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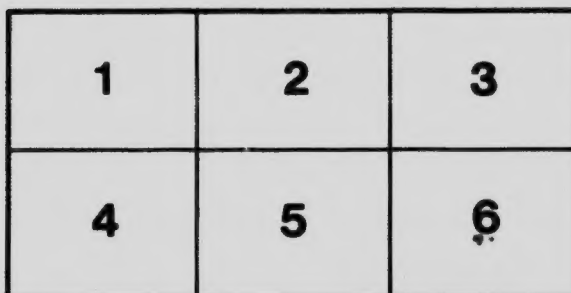
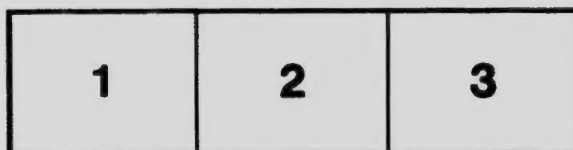
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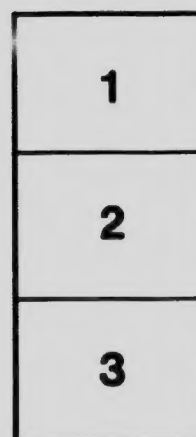
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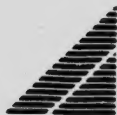
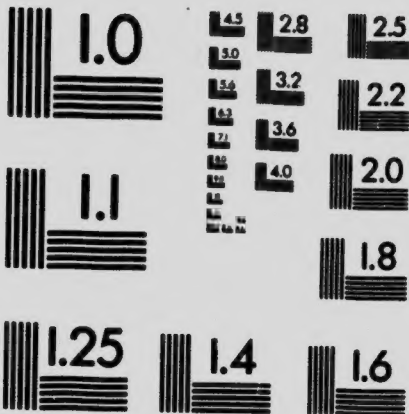
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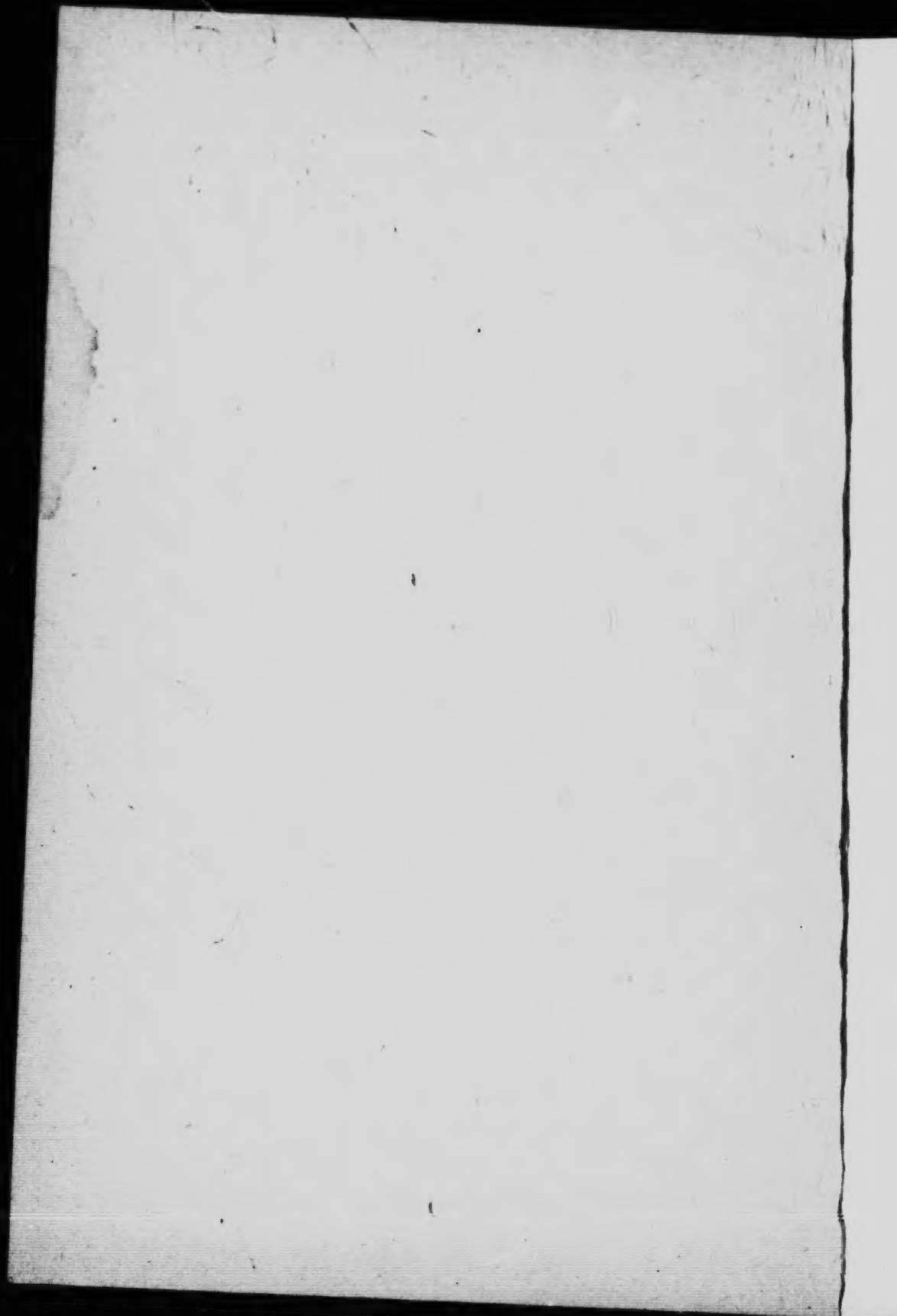


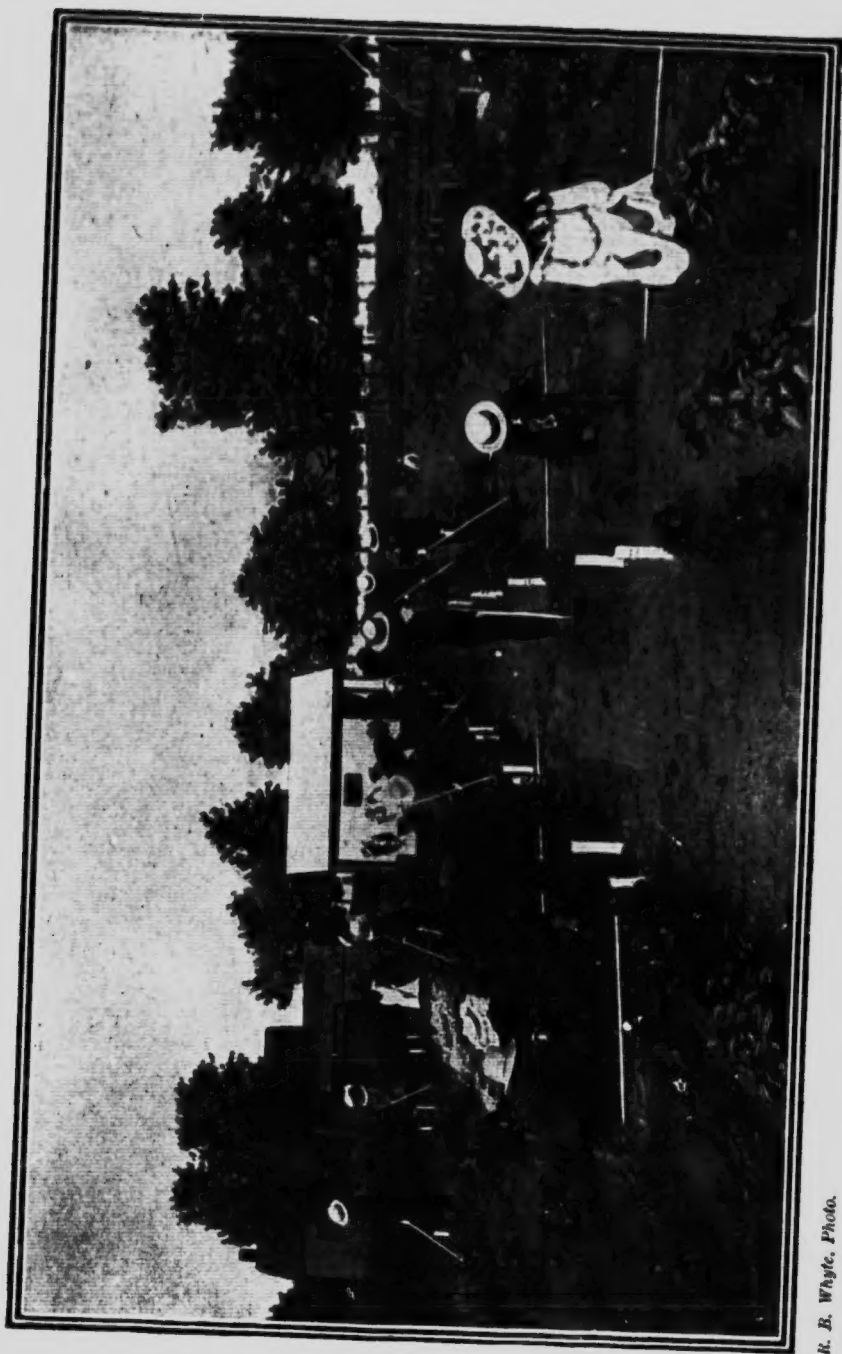
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A MACDONALD SCHOOL GARDEN.

NATURE STUDY AND AGRICULTURE

BY

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INTRODUCTION

THIS volume is written by men who are in love with their work, who are masters of their subjects, who are in sympathy with teachers and children, and who desire to serve them.

Every child begins life helpless, ignorant and selfish. All experiences which help it out of that state are educational in the right direction. Looking to that desirable end, one would hardly choose Reading, Writing and Arithmetic for the foremost places in the course of Study. Since all knowledge begins in wonder, one may be permitted to wonder whether the dullness of some children in school is not usually a symptom of a course of education not wisely arranged, rather than an evidence of sluggish or weak mental faculties.

We are all part of Nature. Our lives—the transient and the eternal, the human and the divine in us—are sustained by natural processes under natural laws. A study of Nature lies at the beginning of all true education; and in the elementary classes Nature Study might well be central, with Household Science and Manual Training on either side of it. These furnish a fine framework for the building of character through education. Subjects, lessons and exercises are worthy of place

as they serve to lead out the powers of body, mind and spirit towards ability, intelligence and goodwill in such a way that these will seek and find expression through co-operation with others for the common good. The methods of instruction which guide children to acquire knowledge from the study of Nature usually influence them to pursue studies in Science, Literature and History. Meanwhile they are being trained to think, to observe, to investigate and to understand. The doing of something definite with their new knowledge, under educational supervision, becomes a means towards the formation of good mental habits. In this volume the lessons have been arranged with the difficulties graduated to suit the growing capacity, strength and intelligence of the learners. Progress may be discerned by an increase in the quickness of perception, by an improvement of the memory for names, facts and rules, and still more by the habits of thoroughness, truthfulness and self-reliance which are revealed by the work done.

Nature Study deals with facts and principles on which the systematic study of Agriculture should be founded. It does for Agriculture what Manual Training does for technical and industrial education. It furnishes a wide basis of general intelligence and ability from which to specialize towards particular occupations.

Because all school training in observing, investigating and recording should include lessons in reading, writing, drawing and arithmetic, the exercises prescribed in this volume become lessons in expression of a highly valuable

INTRODUCTION

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sort. They nourish growth of thought, and also clear and correct expression of thought. They minister to the children in developing intelligence, personal ability and love of working with others to attain some end for the good of all.

We all are trustees of life and its opportunities for the children. The main thing in the trust is to have the next generation of trustees ready for their duty and privilege. "Of such is the Kingdom of Heaven."

To love to live is well,
To live to love is better,
And this the best of all,—
To love to live to labor.

JAS. W. ROBERTSON.

Ottawa, Canada.

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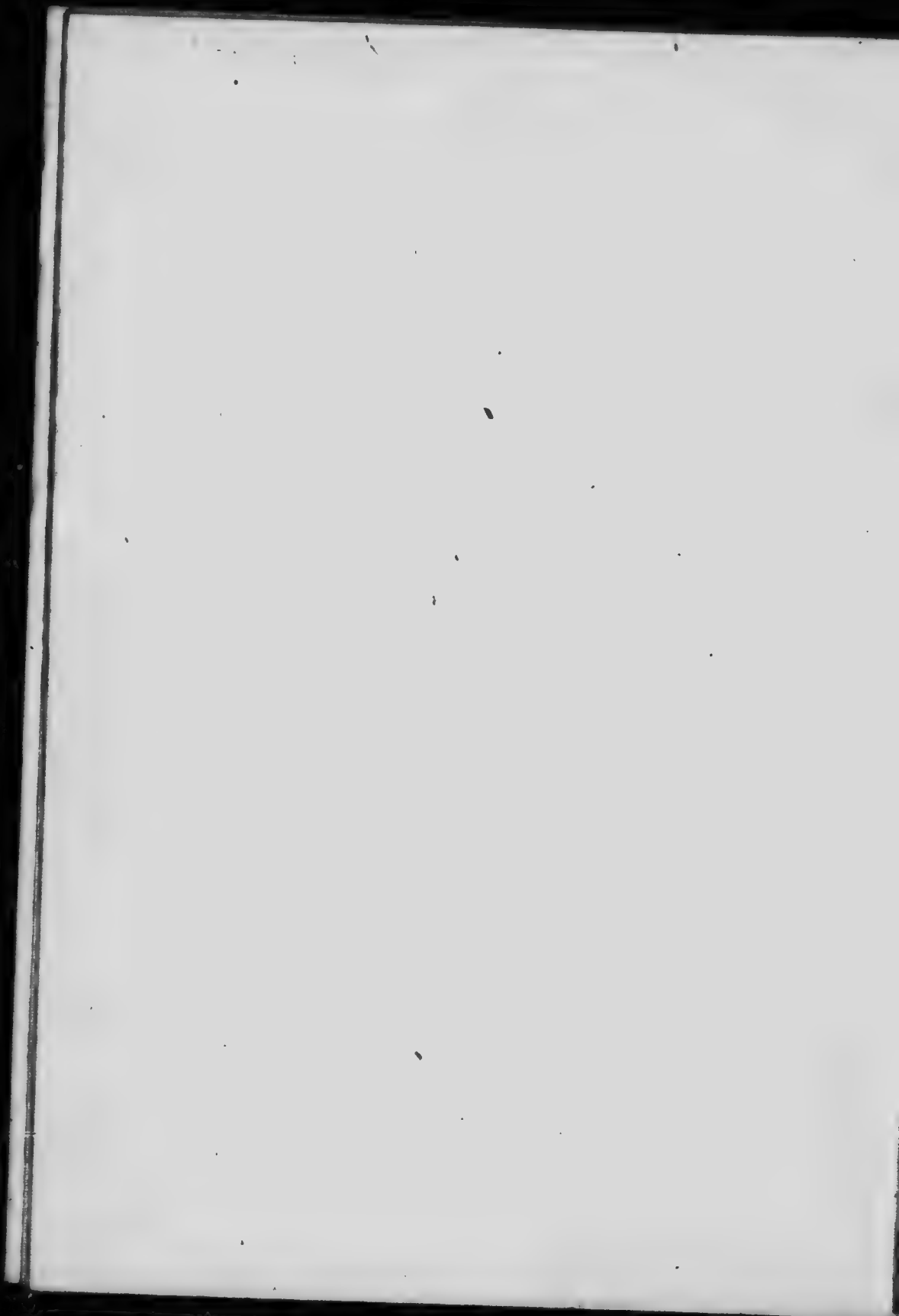
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FIRST YEAR

AUTUMN LESSONS

I. GERMINATION AND EARLY GROWTH OF PLANTS

Material to be prepared in advance.—A supply of seeds for the class, some of this year, some of the year preceding ; a few potato tubers ; two or three flower-pots filled with soil ; a number of plates and saucers, and of circular pieces of blotting or filter paper or of flannel for the germination experiments.

WE are about to begin to-day a course of lessons on plants. We shall try to find out something about their lives by watching them from day to day, and by trying various experiments with them. I am sure you will learn to like them better as you become better acquainted with their ways of life, and see that they—like ourselves, and every living thing—have their own work to do, their own difficulties to overcome, and their own enemies to avoid.

We shall find, too, in our studies of plants, that there is a vast number of kinds or *species* of

them, of all forms and sizes, from those so minute that they are far too small to be seen with the naked eye, to the great trees of the forest. You have noticed, probably, that some plants never bear flowers, no matter how long they live, and that these flowerless plants do not bear seeds. Since most of our conspicuous and useful plants bear flowers and grow from seeds, we will begin our studies with the *seed-plants*—plants which may be grown from seed.

To begin with, I must ask you to get together the seeds of a number of common plants—beans, corn, wheat, peas, clover, etc., including some tree seeds. Get some seeds which were ripened this year, as well as some left over from last year. They all look dry and lifeless, yet no doubt the most of them are capable of awakening. They are merely dormant, asleep as it were, or undergoing hidden changes which make it possible for them to be roused into activity by influences from outside of themselves. The mere lapse of time will not arouse them, nor will warmth and sunshine alone set them free from the thrall which binds them. When seeds are planted by the farmer or gardener in spring, they are also supplied with soil and water. Then some kinds begin to sprout (*germinate*) at once; others will not do so unless several months or even seasons have passed since they fell from the parent plant.

Let us try an experiment by which we may learn what agencies stimulate the dormant seed into visible action. Take several flower-pot saucers or plates and place on each two circular pieces of clean porous paper or loose woollen cloths, soaked in water. Scatter a number of seeds of each kind between the wet cloths or papers, putting last year's seeds and those of this year in separate plates or saucers carefully labelled. Cover the dishes with others inverted over them. Set the dishes in a warm place, and look at the seeds every day to see whether they are sprouting or not.

Although the potato is a flowering plant, not usually grown from seeds, but from the tubers or "potatoes," as they are called. It will be interesting for you to try whether the potato tuber of this year will grow this autumn or not. So plant two or three tubers in good soil, in flower-pots or in a box, and keep them warm and moist.

EXERCISES

1. What percentage of the different kinds of seeds and of the tubers sprouted?
2. How did the seeds of this year compare with those of last year in germinating power?
3. Which of the several kinds of seeds germinated first, second, third, and so on?
4. What parts—*organs* as they are called—may be seen in the little plants when they first emerge from the seed-case?

5. Note whether the young plants grow at one end or at both ends, and what new parts appear as they continue to grow ; especially notice the delicate little hairs—finer than the finest rootlets—which form on the roots, and observe whether they are produced at the tip of the root or rootlets, and how far back they extend. These are the root-hairs. What is their color ? Are they branched or simple ?

6. Keep the young plants supplied with water for some time longer, to find out how long they will grow without soil, and what new parts will appear.

II. THE ORGANS OF VEGETATION

Material.—The dishes used in the preceding lesson, with the young plants therein ; fresh green leaves—some thick and tough, some soft and tender ; small saucers or nappies for holding alcohol ; test tubes and spirit lamps (or, instead, enamelled cups and a stove).

We shall now examine the leaf to learn something of its structure and of the materials which make it up. By scraping the upper side of the leaf carefully with a sharp knife-blade, you will be able to raise a little piece of the *skin* ; then scrape through to the lower skin. Decide whether the whole leaf is covered above and below by this thin skin, whether the skin is colored, and whether it will allow light to pass through it. By holding between you and the window a leaf which has been scraped through in places to the upper skin, you will find whether the skin is transparent or not. Of course unless the light can pass through the

skin, none of the sunlight which falls upon the leaf can enter its interior.

Take out one of the larger veins of the leaf, scrape it clean; note its color; find whether it is more or less brittle than the material around it, and whether it can be split lengthwise or not. The veins are fibrous woody bundles, forming a framework to support the delicate green substance which occupies the most of the space between the upper and the lower skin. They are, in addition, the paths along which food materials and foods pass.

Between the veins, occupying the space between the skin on the upper side and the skin on the lower side, there must be some other kind of material which gives the leaf most of its thickness. Examine this material by rubbing and squeezing the leaf between your fingers. This juicy part of the leaf may be called the *pulp*.

Boil a fresh green leaf in water, and note the change, if any, in the apparent color of the water and of the leaf. Place the boiled leaf and an unboiled one in hot alcohol or methylated spirits and leave them there until you observe a decided change in the color of the leaf, and in the apparent color of the alcohol. In heating the alcohol, be careful not to set it on fire. The green coloring matter which you have wholly or partly extracted from the leaf is called *leaf-green*. You will find out its use later.

EXERCISES

1. How does the soft green part of the leaf differ from the skin and the veins?
 2. In which of these three—skin, woody tissue and pulp—most of the sap contained? most of the leaf-green?
 3. Find out what liquid the sap mostly consists.
 4. Press a *small* bit of litmus paper into the sap of a leaf. Describe and explain the effect.
 5. Which of the three kinds of material found in the blade of the leaf is most abundant in the leaf-stalk?
 6. Make a collection of leaves which have been partially eaten by insects. Try to find some in which the pulp alone has been eaten by a leaf-mining caterpillar, living and working between the skin on the upper side of the blade and the skin on the lower side.
 7. Make drawings of the leaves of some common trees.
 8. Collect a number of different caterpillars, and place each of them in a wide-mouthed bottle with a little sand or loose soil in the bottom. Keep them supplied with fresh leaves from their food-plants, and watch their behavior.
-

III. ORGANS OF VEGETATION (*continued*)

Material.—A collection of cuttings from various stems and roots, including enough pieces of sunflower stalks and corn-stalks to supply the whole class.

You will to-day examine some stems or branches young and old, large and small, soft and hard, to find whether they are made up of the same or of different kinds of material from the leaf. At the

same time you will compare the structure of the stem with that of the root. You will need to cut the stems off crosswise, and then split the pieces lengthwise several times, testing them in various ways as you proceed, to determine the several different materials of which the stems and roots are composed.

You will find whether stems and roots and their branches are ever protected merely by a thin skin as leaves are, and whether they always retain this thin skin. If not, find when and in what cases it disappears, and what structure takes its place.

In plants like the sunflower and in common trees and shrubs, the parts of the stem and of the root are arranged in concentric circles about the *pith* or soft substance in the middle. The comparatively hard material which surrounds the pith is called *wood*. Outside of this is the *bark*, a mixture of delicate material and tough fibres. Sometimes these are so firm and long that, as in the case of the flax, they may be used to make thread and cloth. Stems which have a central pith with wood next and bark on the outside are often called *exogenous* stems, because they grow in thickness by forming a new layer of wood outside the old wood every year. At the same time, new bark is formed inside the old. Nevertheless the bark does not become very thick. As most stems grow older, cork arises a little below the surface, cutting off the

water and food supply from the outer parts, which die and fall away, usually in flakes. From the birch, the waterproof corky layers may be peeled off in great sheets which are used to make canoes. The thick cork of an oak found in Southern Europe is of great commercial value and the source of most of our bottle-stoppers.

Upon examination of a stalk of Indian Corn, you will find a different arrangement. The woody bundles run through the stem scattered in every part but more closely packed towards the margin of the stem. There is no central pith marked off from the wood and no true bark. Such stems as these are called *endogenous* stems. They add no new layers of wood to the old, and do not increase very much in thickness as time goes on. Even the great palms of tropical and semi-tropical countries grow but little in diameter after the first two years of their life, and may in time decrease slightly because of the death and peeling away of the outer part of the stem.

The largest plant with an endogenous stem grown in Canada is the Indian corn. Its near relatives, the grasses, as well as the lilies, the orchids and the irises are other familiar examples.

EXERCISES

1. Arrange the stems you have been using into two lots, one of exogenous, the other of endogenous stems.

2. Mention some stems which show by their color that the bark contains leaf-green.
3. When you squeeze the stem of a red clover between your thumb and forefinger it is seen to be a stiff, hollow cylinder which yields to the pressure and flattens out, but when the pressure is removed springs back again. Determine whether the clover-stalk is exogenous or endogenous.
4. Find a stem which contains but one ring or layer of wood between the bark and the pith, and another in which the wood is made up of several layers. Account for this difference.
5. Mention several plants whose stems never have more than one layer of wood. Why is this?
6. Find a stem which shows, in cross-section, radiating lines extending from the pith through the wood. These are called the *pith rays*. They are not really lines, but merely appear as lines when they are cut across. By means of longitudinal section, find what their form is.
7. Examine the stalks of the common grains, and find whether their structure is like that of the sunflower-stalk or that of the corn-stalk.
8. Show which have more surface in proportion to the bulk and weight of material in them—leaves or stems.
9. What are some of the uses of leaves, roots, stems, bark and wood?
10. Gather in a damp place some fallen leaves, one or more years old, and find what part of the leaf is the first to decay, and what parts remain to the last.
11. (a) Make a drawing of a cross-section of a stem of a sunflower, showing the pith, wood and bark, and the relative amount of each.
 (b) Make a similar drawing of a stem which contains several rings or layers of wood.
 (c) Draw a cross-section of a corn-stalk, showing its structure.

IV. THE ORGANS OF REPRODUCTION IN FLOWERING PLANTS

Material.—A set of flowers for each student, illustrating common variations in floral structure. Needles stuck through small corks for handles will be found very useful in examining flowers.

You have all observed that after a seed-plant—a plant which produces seed—has grown for a time it produces flowers. I suppose you have examined flowers before and know the names of their parts. As a review, arrange before you a set of flowers showing as many variations of structure as possible; compare them with each other, and find examples of the different parts and structural features mentioned in the following description:—

The lowest or outermost part of a complete flower is called the *calyx*, and is made up of a circle or set of *sepals*, which may be either quite separate from each other or united at the base into a deep or flat *tube*, with teeth or lobes at the top.

Inside the calyx is the *corolla*, usually more delicate than the calyx and of some other color than green. It may be composed of separate petals, or may be in the form of a cup or tube with a toothed or lobed margin.

Stamens stand inside the corolla. A stamen is usually made up of a slender stalk called a *filament* and an *anther* borne on the filament. The filament

may be very short or absent, the anther being the essential part of the stamen. Find how many little cavities—*pollen-sacs*—there are in the anther of a stamen. Look for some anthers which have not, and some which have, discharged the fine powder (*pollen*) from the sacs. Note where the anther-lobes open to discharge pollen.

In the centre of the flower, you will find one or more pistils containing ovules which will later become seeds. A pistil may be composed of several parts called carpels, or it may be made up of one only. In the buttercup you will see many carpels quite separate from each other and so small and seed-like in form that people are apt to take them for seeds; but if you succeed in opening one of them without destroying the seed you will find that each carpel *contains* a single buttercup seed. So each buttercup carpel is not a seed but a seed-like *fruit*, bearing within it one seed. In some plants, for example the poppy or the apple, the pistil is composed of several carpels, closely united. The number of carpels can usually be told by the number of parts into which the pistil is divided at the top, or the number of little chambers holding seeds in the lower part of the pistil, called the *ovary*.

The pollen formed in the anthers of the stamens is generally necessary for the production of good seeds in the pistil. You can feel a sticky surface

at the top of the pistil in a newly-opened flower and may succeed in seeing grains of pollen upon it. In flowers in which the carpels of the pistil are separate, or partly so, each carpel has a sticky surface (*stigma*) at the top, to which the pollen grains adhere. It is a common mistake to think that the pollen grain itself goes down through the pistil and causes the seeds to develop. The fact is—as can be seen with a microscope—that the pollen grain remains on the stigma, and a long slender tube, called the *pollen tube*, grows out of the little grain of pollen down through the pistil to the *ovule*. This tube conveys a tiny male cell formed in the pollen grain to a little egg inside the ovule which is thus fertilized. Then the egg grows into a baby plant called the *embryo* and the ovule becomes a seed. When this does not happen, perfect seeds that will germinate and produce new plants are as a rule not formed in the pistil.

EXERCISES

1. Find a flower whose parts are in sets of five or of twice five.
2. Find a flower in which the number of carpels is the same as the number of sepals, and one in which the number is different.
3. Look for other numerical differences in the parts of a flower.
4. Look for cases in which *like* parts of the flower seem more or less united, either at the base or at the top.

5. Find examples of the union of *unlike* parts, as when the calyx-tube seems to adhere to the ovary or seed-vessel of the pistil, or when the stamens or petals seem to be "inserted on" or grow out of the calyx-tube.

6. Study flowers in the garden or fields, and find some which are frequently visited by insects. Discover if you can what the insects get from the flowers and how they get it. Find if insects are attracted to flowers from a distance, and by what means.

7. Gather some of the stuff which the insects are taking from the flowers and examine it.

8. Make drawings of several flowers, and of the several parts of a complete flower.

V. ORGANS OF REPRODUCTION (*continued*)

Material.—A set of flowers and fruits, illustrating the relation between the two.

If you will compare some fresh flowers with older ones of the same kind, you will find that some parts of the flower fade and wither, while the pistil not only remains fresh and healthy, but actually keeps on growing till it is much larger than it was before the petals and stamens began to wither and dry up. After a while the pistil, too, ceases to grow. This enlarged ripened pistil is a *fruit*.

Sometimes other parts of the flower combine with the pistil to make the fruit. For example, the part of the apple outside the core is largely the fleshy flower-stalk.

The carpels of which the pistil was composed may usually be counted in the fruit. Sometimes, as in the lily, they show on the outside of the fruit. In other cases, as in the apple, they show only in the interior.

A great many fruits are small and dry and resemble seeds so much that they are called seeds by gardeners and farmers. Each of these little fruits *contains* a seed enclosed by one carpel or more, but the fruit is sown with the seed inside.

In many fruits the carpels open and discharge the seeds. The pod of a pea is such a fruit. When small it was the pistil of the flower. It is composed of one closed carpel containing a row of seeds. It grew on the top of the flower-stalk with the other parts of the flower around it. Try to find it in sweet pea blossom.

Other fruits, like a grain of wheat or a currant, never split to free the seed.

In order that as many plants as possible may find healthy, comfortable homes without crowding one another, seeds should be widely scattered.

There are many interesting contrivances which bring this about. Some seeds and fruits can float long distances upon the water; cocoanuts have been carried a thousand miles in this way.

The wind bears others on their journeys. "Maple-keys," milkweed seeds, dandelion fruits with silken sails are familiar examples. "Tumble-

weeds," like the Russian thistle, roll long distances before the wind, scattering seeds as they go.

Every time you go for a country walk in the fall you are apt to help in the work of carrying baby plants far from their mothers. Clinging to your clothes there will almost surely be burrs, beggar ticks and many of their relatives.

Bright, fleshy fruits attract birds and other animals. But while the fruits are crushed, the seeds generally pass through the digestive tracts of animals uninjured, and may germinate even more easily after such treatment.

Other fruits, like those of the witch-hazel and the wild geranium, burst when dry and hurl the seeds some distance away.

So by one means or another, seeds become widely scattered and if they lodge in a favorable spot give rise to new plants which will have good chances of living and bearing seed in their turn.

EXERCISES

1. Why are the flower, fruit and seed called organs of reproduction?
2. Find fruits which were formed from the pistil of the flower only, and others which include other parts as well.
3. Mention some so-called seeds which are really fruits. Give proofs.
4. Make a small collection of seeds and seed-like fruits which are dispersed by the wind.

5. Make another collection of seeds which are adapted for being carried about by animals for dispersal.

6. How does the juicy pulp of many fruits aid in the dispersal of their seeds?

7. Find a plant which blooms during the first year of its life; one which does not bloom the first year but blooms the second year; and one which does not produce flowers till it is more than two years old.

VI. INSECTS AND THEIR RELATION TO PLANT LIFE

Material.—A set of specimens—living, dead or dormant—put up in bottles or jars, illustrating stages in the life-history of insects.

The majority of insects are not only beautiful, but they lead clean and healthy lives. Perhaps of all insects, bees and butterflies commend themselves most to your kindly feelings—the former on account of the honey they produce, and which we enjoy, and the latter by their pretty colors and graceful flight. When you come to know more about other insects and their ways I am sure that you will find them so interesting that you will wish to study their lives and will lose any foolish prejudices which you may now have in regard to them.

The life-history of an insect is a wonderful story and very surprising to one who follows it for the first time. It includes four stages—the egg, the larva, the pupa, and the imago or adult insect.



THE MOURNING-CLOAK.

1. Eggs greatly enlarged.

2. Full-grown larvæ.

3. Butterfly just out of the chrysalis skin.

From "How to Know the Butterflies."—COMSTOCK. (Reproduced by permission.)

I hope you may have secured specimens of these forms for this lesson. The eggs, usually about as large as pin-heads, may often be found glued in close clusters to branches or leaves. Caterpillars (larvae), hairy or smooth, may be found feeding on leaves or crawling on the ground, and may be brought in small jars or boxes to the school. Pupae may be discovered suspended from branches, boards, or other supports, or enclosed in cocoons.

The final stage of an insect's life—usually winged—is called the imago. If the imagos of bees or butterflies cannot be obtained, those of flies will answer the purpose. The complete life-history of an insect may be summarised as follows:—

1. The *egg*. This stage is dormant and motionless and remains so until the next form—the larva—hatches out of it.
2. The *larva*. The larvae of the great groups of insects differ much in appearance, and receive different names. The larvae of butterflies and moths are called *caterpillars* and may be smooth or hairy. The larvae of flies are called *maggots*; those of beetles are *grubs*. Larvae, no matter how worm-like, should not be called worms, for worms never develop into a higher form as larvae do. In the larval stage the insect is active, crawls about, eats voraciously leaves, fruit, wood, decaying matter, or other insects, according to its taste, and grows so rapidly that it bursts its skin and casts it off (*moults*), sometimes ten times before it attains its full size. When its appetite subsides, the larva may construct around itself a small bag or loose case called a *cocoon*. The cocoon is often composed mainly of its own hair, sometimes of silk drawn from its body, sometimes of

earth or bits of wood stuck together. When the cocoon is completed the larva turns into a pupa. Some larvae, instead of making a cocoon, suspend themselves from a support and are transformed into a pupa, the outside of their bodies becoming hard and dry, to form a protective case.

3. The *pupa*. In this third stage the insect is usually dormant and inactive. Many insects pass the winter as pupae. As we have seen, the pupa is commonly enclosed in a cocoon, from which at last the insect emerges in its adult form—the *imago*—usually with wings.

4. The *imago*. This is the final form of the insect. It is active and often able to fly with great rapidity, and for long distances. Most insects in this stage eat or drink, but they do not grow. You may often see them flying from flower to flower sipping nectar, and sometimes collecting pollen. Judging from their gay manners one would think that this is the happiest part of the insect's life, but it is the stage which ends in death. Before it dies, however, the insect deposits its eggs on or near the food-plants or food-material of its larva. In some insects, such as grasshoppers, the distinction between the larva and the pupa is not clearly marked, and the pupa is active and similar to the adult in form.

Insects do an immense amount of damage by devouring the leaves of our cultivated plants and forest trees. They often live in fruits, and even in the stems of trees, gnawing passages through the wood. Some species suck the juice out of leaves and tender stems. Mosquitoes and house-flies spread sickness and death by conveying the germs of disease and depositing them on or in our bodies or our food. Although we have discovered various methods of keeping destructive and noxious insects in check, they still continue to put us to great

trouble and loss. Indeed the damage done throughout the country may be reckoned in millions of dollars every year.

Still we should remember that insects do a great deal of good. They pollinate the flowers of our fruit trees and vegetables, thus insuring the production of seed. Some kinds act as scavengers, devouring foul and decaying matter; others—the lady-beetles for instance—benefit us by eating the insects which feed upon our crops. The “little busy bee” is our unconscious benefactor, since we regularly rob it of its stores of honey.

EXERCISES

1. Collect some caterpillars and put them with leaves from their food-plants, in fruit jars, wide-mouthed bottles or boxes with the front made of glass and the back of wire netting. If you use jars, the mouths may be covered with thin cotton cloth fastened on with a rubber band or a string. Put an inch or two of sand or loose earth in the bottom of the jars or boxes. Supply the caterpillars with fresh leaves until they begin to prepare to pupate (turn into pupae). If you get an opportunity, watch the process of cocoon-making.
2. After the caterpillars have transformed into pupae, set the jars or boxes away in a cool place, to await the coming of spring.
3. Examine the external structure of an insect in the imago state. Note the three principal divisions of its body, and that these divisions are made up of short joints or segments. Count its wings, legs, feelers and eyes.
4. Find an insect which bites off and chews its food, and another which does not chew, but *sucks* the juice of plants. Watch the processes of chewing and sucking.
5. Make a sketch from life of an adult insect with wings.

VII. HOW TREES AND SHRUBS PREPARE FOR WINTER AND SPRING

Material.—A set of branches from different species of trees, including some fruit trees.

How easily the leaves break off from the branches and shrubs at this season of the year. They may be seen fluttering down to the ground on calm days when not the slightest breeze disturbs them. Their own weight is sufficient to break them off. Carefully pull off some leaves still clinging to the branch, and find at what place the leaf-stalk breaks. Then test it to see whether it is as easily broken anywhere else. It is evident that this brittle layer across the leaf-stalk must form towards the autumn, for if it had been present in summer the leaves would all have fallen off then. So most of our trees and shrubs act as if they deliberately planned to get rid of their leaves in the autumn. Why should they? It must be of some advantage to the trees to be leafless in winter. Whatever the work of leaves may be, it must be impossible for them to continue it during the cold season.

Look for the marks left by last year's leaves when they fell. These marks are called *leaf-scars*. Compare them with the leaf-scars of this year. What do you find close above the leaves or leaf-scars of this year? These little knobs are the

winter buds; but there are no buds above last year's leaf-scars in many cases. Instead, there is usually a branch. Since this year's leaves have buds above them, it is clear that last year's leaves had buds above them last autumn. But the buds of last year have since grown out into branches. It seems then that each *side-bud* develops, not into a leaf as some imagine, but into a whole branch bearing several leaves. Even after the leaves have fallen, the number of leaves which came from one bud can be determined by counting the leaf-scars on the branch which bore them. It will be interesting to dissect one of the larger buds with a needle to see whether its structure affords any proof that the bud would become a branch bearing a number of leaves.

Covering the delicate parts of the bud within, you often find dry scales overlapping each other, whose use is evidently to protect the undeveloped branch. These *bud-scales* may be regarded as another form of leaves, for they grow on the same stem upon which the foliage-leaves grew, and are more or less leaf-like in form. When the bud-scales fall off in spring, they leave little curved scars to mark their places. These sets of bud-scale scars mark the place of last year's buds; and the position of the buds of earlier years may often be determined by their means.

Let me next call your attention to the *end-buds* (terminal buds) which you find at the top of branches and branchlets which have grown from side-buds. By studying your branches you will be able to locate the points where the terminal buds of last year and of several preceding years grew. When you have found the position of last year's terminal bud, you will see at once how much the branch has increased in length since last winter. In many branches you can find how much the branch extended its length during each of several preceding years. Find in which of these years the branch grew most rapidly.

The buds which we have been discussing are called *leaf-buds*. Each of them develops into a branch (or a continuation of one) bearing foliage leaves. In addition to the leaf-buds, trees prepare *flower-buds*, which develop into short branches bearing flowers. Find some of these flower-buds. How strange it seems that the trees and shrubs prepare for the approaching winter with its frosts and snow, and for the genial spring to succeed the winter!

Each tree not only forms miniature branches covered them with waterproof bud-scales, ready to start into activity and growth as soon as the spring sun arouses them, but it stores up food in the branch near the buds to nourish the developing buds during their early growth.

There is a notion that the scales which cover buds keep them warm in winter. It is impossible that such thin coverings could be effective in that way during our severe winters. It seems that the chief use of the scales as well as of the resinous substances which sometimes stick bud-scales together, is to keep the buds from drying up during the dormant season.

EXERCISES

1. Compare leaves that have fallen from the trees with some fresh leaves from other plants. What differences do you observe?
2. Find whether stems which die before winter comes—that is annual stems—have any buds; and if you find such buds, compare them with those of plants whose stems live through the winter.
3. Try whether you could tell the different trees and shrubs apart by the shapes of their leaves, and, after the leaves have fallen, by their leaf-scars and buds. Make a collection of leaves and twigs from the common trees.
4. Make a drawing of a short branch, showing the buds and leaf-scars.
5. Look for examples of other plants besides trees and shrubs, which make preparations for spring by storing up food or in other ways.
6. What relation can you discover between the arrangement of the leaves and that of the buds and branches?
7. Find, by cutting a branch off in several places, how many rings or layers of wood there are in the segment which grew this year from last year's terminal bud; how many in the part which grew out last year; and in the part which has been growing for three seasons. In the last case, show which is the oldest and which the newest layer.

VIII. OTHER SEASONAL CHANGES IN AUTUMN

The trees and shrubs—plants whose stems persist and continue to increase in height and diameter year after year—make preparations even in autumn, as we have seen, in order that they may the better endure the rigors of winter and make a quick start in the spring; but there are many perennial plants whose stems die down to the ground every autumn, and are replaced by new stems with new leaves in the spring. Such plants as these lay up a store of food in underground parts, which, though the soil may be frozen hard about it, remain alive but dormant throughout the winter. Some of these, the dandelion for example, pack away a supply of food in their roots; some, like the onion, in a close cluster of fleshy leaves called a *bulb*; while the potato and others develop underground stems, either tubers or root-stocks which they use as storage organs.

Annual plants, such as wheat, which only live one year, store up food in their seed to nourish the young plants of the next generation. The parent wheat plants, apparently exhausted by the effort to provide for their offspring, then wither away and die outright early in the autumn. So when we eat onions, potatoes or wheat bread, we are regaling ourselves on the food which the plants stored up for themselves or for their successors.

The great majority of our birds are gifted with some kind of foresight which often warns them, while the days are fine and warm, that a season which they have never seen is approaching, when it would be difficult or impossible for them to keep warm and find enough food to sustain them. Gradually, we know not the day or the hour, each species departs for the sunny south.

If you are fortunate enough to be lovers of birds and bird songs you will feel the solitude and silence which slowly takes possession of the fields, groves and forests as the feathered tribes depart and leave no mementoes save their empty nests. Our regret is softened by a certain hope that the birds, having braved all the dangers of the journey, will return in the spring-time in a happy and tuneful mood.

Many will not have very far to travel, as they only go a few degrees to the south, but others keep on southward until they reach Mexico or Central America, or, crossing the Caribbean Sea, enter South America. The bobolinks are said to cross the equator and not to stay their flight until they reach southern Brazil, thousands of miles from the cosy homes where they first saw the light.

A few of the birds remain with us throughout the year. You will see them sometimes in the winter, and you may have an opportunity to help

them through by throwing them crumbs from your table.

The insect tribes, as well, have learned to prepare for winter. You have all noticed how scarce insects seem to be in the cold season. There is no hum of bee, no buzzing of mosquitoes in the houses, only an occasional house-fly is seen on a warm day. This great stillness in the insect world does not mean that the insects have migrated like the birds to a more genial climate. They are only dormant, and the various resting-places in which they pass the winter are not hard to find. In late autumn, hidden away in crevices, or under stones, suspended from boards or rails, glued to branches or leaves, hidden in moss or buried in the earth, usually as eggs, but sometimes in the caterpillar or the winged state, they await the great awakening.

The various wild creatures of field, forest and stream have solved the problem of winter existence in different ways, each forming habits in accordance with its own capabilities.

While all these preparations are being made throughout the animated world, the shortening days, the falling temperature and even the position in the heavens of the sun, moon, planets and conspicuous constellations mark the slow but steady approach of winter.

EXERCISES

1. Find some plants, cultivated or wild, whose stems die down in the autumn, while their roots, underground stems and buds remain dormant, ready to start in the spring. Find where their food is stored.
 2. Examine specimens of garden plants which store up food in their roots before they blossom in the same or the following year.
 3. Observe as far as you have opportunity, the order of departure of the common migratory birds.
 4. Measure your shadow or that of some fixed object once a month at the same hour of the day, until the end of the year. How much does the length of the shadow change in three months' time? Account for this change.
 5. Record the length of time from sunrise to sunset once a month during the last four months of the year. Explain the change in the duration of daylight.
 6. Record once a week during the same months the outdoor temperature as indicated by the thermometer. Take the temperature always at the same hour of the day. State the amount of variation and explain.
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IX. SOME IDEAS ABOUT MATTER

Material.—A pail of water, glass jars or bottles, test tubes or enamelled cups, spirit lamps, a small vial, a tumbler, a little aqua ammoniac (ammonia in water), sugar and salt.

All boys and girls of your age have noticed that wood, iron, water, milk and other things, take up room, or in other words, *occupy space*. We apply the term *matter* to anything that will occupy space.

It may never have occurred to you that there are things which are quite invisible to us which occupy space as completely as those forms of matter which we can see. Let us consider the air in what we call an *empty* bottle. Push the open bottle, mouth downward, into a vessel of water. You will find that the water does not enter the open mouth of the bottle and fill the bottle when you push it down beneath the surface of the water. If you push the bottle under water and incline it on its side, you can see the bubbles of air coming out of the bottle, and as the air goes out the water rushes in, but not before. The air occupies space, for it excludes the water from the bottle; so air is a kind of matter.

A portion of matter of sensible size is called a *body*. The amount of space included within the limits of a body is called its *volume*. A body does not necessarily fill all the space included within its limits; for instance, sand and gravel do not. The volumes of bodies are expressed in various units, such as cubic inches, cubic centimeters, gallons and bushels.

The different *kinds* of matter are called *substances*. For example, wood, water and air are substances. A substance such as wood, which is so firm or rigid that it will not flow, is called a *solid*. Substances which will flow readily, like water and air, are called *fluids*. You have noticed

that if you leave some water in a corked bottle, the volume of water remains the same. The water lies in the bottom of the bottle; but if you catch some invisible ammonia in a small open vial and set it in a large bottle, and cork the larger bottle, you will find in a short time, by the smell, that the ammonia has spread throughout the larger bottle. The ammonia does not tend, as the water does, to retain its volume, but tends to increase in volume, and spread throughout all the available space. A fluid such as water, which tends to hold together and retain its volume, is called a *liquid*. Fluids such as ammonia and air, which tend to diffuse through space and become thinner and thinner, are called *gases*.

Many substances may exist either as a solid, a liquid or a gas. Water is one. In the form of ice it is a solid; when the ice melts it is liquid water; as invisible steam it is a gas. The visible water vapor which we see issuing from a boiler or a kettle is not steam. True steam or gaseous water is invisible. If you watch visible vapor forming at the mouth of a kettle, or at the mouth of a test tube in which water is boiling, you will see that the visible vapor is formed from an invisible gas. This invisible gaseous water is the true steam. Leave some water in a tumbler in the room. The water gradually escapes from the tumbler and leaves no trace behind. It has diffused

through the air; but it was not as a liquid that the water escaped from the tumbler, else you could have seen it going. The liquid water changed into invisible gas (steam), and it was the gas which spread through the air of the room. We say that the water evaporated.

Put about half a teaspoonful of sugar into a cup of water, and as much salt into another cup of water. If the sugar and salt do not disappear entirely in a short time, gradually add water until they do. Although you cannot see the sugar or the salt now, you can taste them in the water. They seem to be in a liquid state, like the water itself, and so cannot be distinguished by sight from the water. The sugar and salt are said to be *dissolved* in the water, and the two mixtures are called *solutions*—one a solution of salt, the other a solution of sugar in water. Boil some of each solution in a test tube, and catch the escaping vapor in a cold bottle. Taste the condensed vapor and the substance left behind in the test tube. The liquid you collect in the bottle is *distilled water*. You now see how to separate a dissolved solid from the liquid in which it was dissolved.

EXERCISES

1. Find several solid substances which will not dissolve to any perceptible extent in water.
2. Set a clear solution of salt and one of sugar aside in a

corked bottle, till you have decided whether the salt and the sugar will become solid again and settle to the bottom of the water. Then leave the bottle open till the water evaporates, and examine the dry residue.

3. Find a solid, other than ice, which will become a liquid when heated, and another solid which cannot be fused (liquefied by heat).

4. Find the volume of a rectangular box 12 in. long, 8 in. wide and 5 in. deep. Explain the process.

5. What volume of sand would the before-mentioned box hold, supposing the box to be made of material $\frac{1}{2}$ in. thick?

6. (a) Give reasons for thinking that air has weight.

(b) What do you think is the cause of weight?

X. SOMETHING ABOUT WORK AND ENERGY

Material.—Spirit lamps, a piece of coarse iron wire, a vulcanite (hard rubber) comb, a piece of woollen cloth, silk thread, balls of dry sunflower pith, small thin pieces of various metals, and light pieces of several other substances, slender sewing needles, small pieces of cork, earthen bowls or saucers filled with water, and a good horse-shoe magnet.

In order to do work we must move some material body, or cause one that is moving to go faster or more slowly, or in a different direction. So you see, you are really working when you are playing, for you are moving things.

All of you have had the experience of working or playing till you felt tired. Now, I think you will admit that when you feel tired you really feel

as if you had lost something—that you have less of something than you had before. That which you lost in consequence of working is called energy. *Energy is the ability to do work*, and you lost some of that ability. However, you will get a fresh supply to make up for what you have lost.

You must have observed that the amount of energy a body has does not depend on its size or the quantity of matter in it. Apparently an ounce of gunpowder has more energy than a pound of clay. Certainly a hot piece of iron has more energy than the same piece when it is cold, for it can do work when hot which it cannot do when cold. For instance, it could burn a hole in a board. When it is doing that it is doing work, for it is moving the parts of the wood. If you lay a hot piece of iron on a cold piece the cold piece becomes warmer—rises in temperature. This is a case in which energy is transferred from one body to another, for the energy of the hot piece becomes less, while the energy of the other becomes greater.

Hang up balls of dry sunflower pith and some light pieces of metal and other substances by threads of silk. Try whether a hard rubber comb will have any visible effect on them when held near without touching them. Then rub the comb vigorously with a piece of flannel and hold it

near the suspended objects one after the other. The flannel and comb should be warm and dry in order to get the best results. You will find the comb will do work after being rubbed that it could not do before—that is, it gained energy while you were rubbing it. You lost muscular energy in rubbing the comb, but of course the comb did not gain muscular energy, for it has no muscles. The energy acquired by the comb is called *electric energy*.

This experiment illustrates another case of transference of energy; but the energy was transformed as well as transferred.

You will find that a magnet will not act on all substances which the electrified comb acts upon; it has another form of energy—*magnetic energy*.

You all know that heat may be transformed into light and light into heat. Later you will learn how green plants store up energy obtained from sunlight. So, the coal derived from forests which flourished long ages ago, contains a great quantity of imprisoned energy. When coal is burned, this energy is set free in the form of heat, which warms our houses, changes water into the steam used to drive great engines and is, in short, the source of the energy used in practically all of our manufactories.

When you heated the iron you were imparting

heat energy to it. The iron weighs no more when it is hot than when cold. The heat increases its energy, but not its weight. The comb, too, when electrified, has more energy than before, but you will find that it weighs no more. Matter has weight, but energy has no weight.

In fact, we are now sure that energy is motion. Heat, light, electric and magnetic action are all waves in something called *the ether* which must fill all space, extending beyond even the most distant stars. Through it, heat and light travel more than 90,000,000 of miles from the sun to the earth. We cannot detect the presence of the ether by our senses, but we perceive the vibrations which pass freely through it and call them by different names. But the differences between heat, light, the electric waves used in wireless telegraphy and those invisible waves which are especially active in bringing about chemical changes, seem to be only those of wave length. Those used by a wireless telegraphy apparatus are miles long. The longest heat waves which have been measured are only a little over one five-hundredth of an inch in length. These ether waves are transverse waves, that is they resemble those made on the surface of water by throwing a stone into it. The water moves up and down nearly at right angles to the surface, although the waves themselves move along the surface.

EXERCISES

1. Try to electrify other bodies besides the comb.
2. Find by experiment whether electrical energy will pass from one body to another without being transformed.
3. Find what substances are attractable by the magnet, and some which are not.
4. Rub your knife-blade with a magnet and hold the knife near a needle. Explain the result.
5. Rub a steel needle with one end (*pole*) of the magnet several times in one direction. Stick the needle through a small piece of cork and float it evenly on a dish of water placed in such a position that the action of the needle will not be affected by objects made of iron or steel. Note the direction in which the floating needle comes to rest on the water. Swing it half way around and let it go again. How does it act? You have just made a simple form of the mariner's compass. Point out its use.

WINTER LESSONS

XI. CONTENTS OF THE POTATO TUBER

Material.—Potato tubers for the class, test tubes, spirit lamps, iodine solution (obtainable from a druggist) may be diluted with methylated spirit, thin white cotton cloth (cheese cloth) in square pieces, saucers or glass nappies. If test tubes are not available, the potato juice may be heated and water boiled in enamelled cups.

WE noted in a preceding lesson that the storage of food for future use was a common habit among plants. It is now in order for us to examine some storage organs to find the principal substances they contain. We will begin with the potato tuber, commonly called a "potato."

Before we proceed to search for the principal substances of which a potato tuber is composed, note the arrangement of the buds called the "eyes" of the potato. Cut the tuber in two, crosswise, and find the parts corresponding to the pith, wood and bark of an ordinary stem. Although the lines marking off these three divisions may be seen, you will find the materials in them very different from those of the corresponding parts in the stem of a tree.

You will notice that the interior of the tuber

is quite wet with a watery liquid, which you can identify by its taste and lack of color to be mostly water. Try the effect of pure water and then of vinegar on litmus paper. Now press a piece of blue litmus paper into the watery juice of the potato. What change of color do you observe? The change in color plainly indicates that the juice is not pure water, but has some substance dissolved in it. The change you observed is characteristic of substances called acids, and indicates the presence of an *acid* in the potato juice.

Reduce half of a potato to a fine pulpy mass, by scraping it with a knife or a grater. Place the pulp in the middle of a piece of thin, bleached cotton cloth (cheese cloth). Gather the cloth up into the shape of a bag, and squeeze the juice out into a dish. Add a *little* water—not as much water as juice—and wet the pulp from time to time by pressing the cloth into the juice and water in the dish. By repeated wetting and squeezing you will get out of the pulp nearly everything that will pass through the meshes between the threads of the cloth.

On examining the contents of the dish you will find that some white solid material has passed through the cloth along with the water. Stir this up with the water and juice, and empty everything—solid and liquid—that passed through the cloth into one or more test tubes or into a small bottle,

and let it stand until the solid substance has settled to the bottom.

Then pour off some of the liquid into a test tube. Heat the liquid—but not to the boiling point—until a solid substance forms in the water and may be seen mixed with or suspended in the water. Allow it to settle. Why could you not see this solid substance before you heated the water? It must have been dissolved in the cold juice, but have become solid when the water was heated. This white substance—which is soluble in cold water, but becomes solid in hot water—is a protein of which white of egg is a simple example. Add a little iodine solution to it and note the effect. Insoluble proteins are also present in the potato in very small amounts.

Next turn your attention to the substance which settled to the bottom of the watery juice at first. Pour the liquid off. Though this sediment is white, it is not a protein. How could it pass through the cloth in a solid state? Try to find this out by examining the sediment. This white substance is called starch. You can tell by the amount you obtained whether it forms a large part of the tuber or not.

Mix a *little* of the starch with an inch of water in a test tube, and boil the water. You will thus find whether the starch will dissolve in hot water or whether it will settle to the bottom as it did at first.

Mix a *very little* of this mixture of starch and water with an inch or two of *cold* water in another test tube, and add a few drops of iodine solution. If you have done the experiment properly you will obtain a beautiful color, very different from that of the iodine itself. This is the iodine test for starch, and will enable you to distinguish starch from other white substances, and to detect it when mixed in very small amount with other substances.

Turn to the material you left in the cloth. Though white it is evidently not starch, else it would have gone through the cloth with the rest of the starch. It differs from the starch in not being made up of grains. This insoluble white substance is called *cellulose*; it is somewhat like the substance already found in wood, but it is not made up of fibres like the woody fibre of leaf veins and of ordinary stems. If you like, you may boil in water a little of the insoluble material left in the cloth, and test it with iodine, to find whether any of the starch remained in the cloth with the cellulose. You will probably find some starch remaining with the cellulose, of which the potato contains a very small amount; although there is enough to keep the tuber in shape after it is peeled, which the loose grains of starch could not do. Besides the cellulose a little fibrous, woody material is present.

It is evident that the skin or peel of the potato

must contain some substance through which water can only pass very slowly, for if you examine an old potato you will find that it is still quite juicy. The tough layer of waterproof material which covers the potato is really cork. This corky layer is similar to that in the bark of a birch tree, and keeps the water in very effectively.

We have now found that there are six different substances in the potato; but do not conclude that there are no other substances in it. Which of the substances in the potato tuber are to be regarded as food stored up for the future use of the potato plant? You could decide this by considering what substances, found in considerable quantity in the tuber, are not found in dry woody stems, or only in small amount. Cut out a narrow strip from the potato, twist a fine iron wire (florist's wire) around it, leaving part of the wire to use as a handle, and heat it in a lamp or other flame. At first it blackens or chars, but after a time a white or gray substance appears outside the black. Press this gray material against a small bit of wet red litmus paper. The paper should change color. A substance which has the observed effect on red litmus is called a base or alkali, and is said to be alkaline. You will notice that the gray substance resembles wood ashes. Try whether wood ashes are alkaline. You will thus find that a potato contains a small amount of *ash*.

EXERCISES

1. Name the different substances you found in the potato tuber, and tell how to distinguish each from other substances.
 2. Test a boiled potato for starch, simply touching it with weak iodine solution.
 3. Bury a few tubers in the soil out of doors. Mark the spot, and leave them there for the winter to find whether they will survive.
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XII. THE CONTENTS OF A CARROT

Material.—Spirit lamps, porous paper (filter paper), Fehling's solution, if procurable, molasses or glucose, iodine solution, several carrots, a small funnel. If your druggist does not keep Fehling's solution in stock, you may get him to prepare some for you, according to the following directions. The quantity may be varied, as long as the proportions here given are observed: Dissolve 14 grams of copper sulphate (blue vitriol) in 200 grams of water, and put this solution (a) into a bottle. Dissolve 69½ grams of Rochelle salt and 64 grams of caustic potash in 200 grams of water. Keep this solution (b) in another bottle. When these two solutions are mixed in equal volumes you have Fehling's solution. Do not mix the whole at once, as Fehling's solution does not keep very long.

You cannot find any buds on the sides of the carrot as you did on a potato. This indicates that the carrot is a root and not a stem, except at the top where the leaves grow. Leaves never grow on a root, so the top of the carrot must be a very short stem. All the rest of it, since it bears neither leaves nor buds, is of the nature of a root.

Cut a carrot across, and also lengthwise through the middle, and look for the parts corresponding to the pith, wood and bark. You will find little, if any, fibrous wood in the woody region of a carrot of the first year. Note how thick and fleshy is the part which represents the bark, and how small the pith. Observe also the *pith rays* arising from the pith and extending through the wood zone.

Prepare some carrot pulp by scraping a carrot as you did the potato in a former lesson, and squeeze the juice through a fine white cloth. Then test the juice for acid with litmus paper. Note also whether the amount of water is large or small.

Test for a soluble protein by heating the juice in a test tube. If present, it will probably be stained yellow by the substance which colors the carrot.

Test part of the juice, after it cools, for starch with iodine solution.

To remove solid matter, filter some of the juice, *previously heated*, through porous paper. Put into the test tube about an inch of the filtered juice (that is, enough to fill the test tube to the depth of an inch). Add enough Fehling's solution to impart a blue color and heat the mixture. There should soon be a decided change of color in the mixture. Heat a little of Fehling's solution by itself. No change of color should ensue. We can only explain these facts by the supposition that the juice of the carrot contains some sub-

stance which will act on Fehling's solution in the manner observed. Why could we not see this substance in the filtered juice? It must be soluble in water, else we would have seen it. Consider whether it could be starch, a protein or cellulose.

The sweetish taste of the carrot suggests that the substance we have found in the carrot might be sugar. To test this, dissolve a very little molasses or grape sugar (glucose) in an inch of water in a test tube. Add Fehling's solution and apply heat. Sugars such as glucose and others which act in this manner on Fehling's solution are called reducing sugars. The carrot is said to contain more than one kind of sugar, but the principal variety in it is *fruit sugar*. If Fehling's solution is not obtainable, the *taste* test must be accepted as evidence of the presence of sugar.

Examine the residue of the pulp left in the cloth, and decide whether it contains cellulose similar to that of the potato.

EXERCISES

1. Name the different substances you found in the carrot, and tell how you distinguish each from the others.
2. Get a carrot with some small roots (secondary roots) branching from the main one. Slice the carrot and find whether the secondary roots start from the pith or from the wood zone.
3. Dissolve a little cane-sugar in water and heat it with Fehling's solution. Does it behave like grape sugar?

4. Test a parsnip, a beet and a turnip for starch and for sugar.
 5. Find whether a carrot contains any ash, and if so whether the ash is acid or alkaline.
 6. Plant in flower-pots, or in the garden, when spring comes, a carrot, parsnip, beet and turnip, and note what becomes of the food stored in the roots. When the plants have fully matured, collect and compare their fruits.
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XIII. WHAT WE CAN FIND IN A GRAIN OF WHEAT

Material.—Wheat grains and flour, saucers or small bowls, pieces of thin white cotton or linen cloth, iodine solution, Fehling's solution.

We shall use ordinary wheat flour in our experiments to-day. Flour is made from wheat grains by grinding and sifting. Of course, whatever we find in the flour must have been in the grain. If you crush a grain of wheat, you can discover why the flour is different in color from the grain.

Make a ball of stiff dough as large as a small apple by mixing wheat flour with water in a dish. Allow the dough to stand half an hour; then put it into a cloth, soak it in a little water in a shallow dish, and squeeze the water through the cloth, repeatedly, into the dish. Then spread the cloth out in another shallow dish, and pour water slowly over the dough, working the dough with your fingers as you proceed. Keep pouring the water off until it becomes quite clear. The part of the

flour left in the cloth will display some properties different from those of anything we found in the potato or the carrot. If you have done this experiment successfully, you will have left in the cloth a substance which will stretch a good deal without breaking, and spring back quickly when you let it go after stretching it. It will also form strings or fibres when you pull one part of it away from the rest. This substance, which is a very valuable part of the wheat grain and flour, is called *gluten*, a mixture of proteins insoluble in water. Dry the gluten and preserve it for a future lesson.

Turn to the white substance which went through the cloth at first with the water. Note whether it dissolved in the water or settled to the bottom. Boil a very little of it in water and apply the iodine test. Decide which exists in greater amount in the wheat flour—gluten or starch.

Since sugar readily dissolves in cold water, you can find by testing the water used in saturating the flour with Fehling's solution, whether the wheat flour contains any appreciable quantity of reducing sugar.

The wheat plant, we find, stores up a generous supply of two substances in its seeds, and that not for itself—for the plant which bears the seed dies as the seed matures—but for its offspring, the young wheat plants, which will grow from these seeds. It was different in the case of the carrot.

The first summer of its life the plant stores up food for its own use the next year. It will then blossom and form seeds with food for the tiny plants in the seeds.

EXERCISES

1. Touch a piece of wheat bread with iodine solution, and explain the result.
2. Test Indian corn and other grains for starch, sugar, gluten.
3. Pulverize a bean and test it for starch and for proteins.
4. Germinate wheat grains in a box of earth and observe the early development of the young plants.

XIV. THE COMPOSITION OF CELLULOSE, WOOD, STARCH AND SUGAR—CHEMICAL UNION.

Material.—Some small pieces of wood, cotton wool, starch, sugar, spirit lamps, test tubes with corks.

We have found that a potato contains water, starch, proteins, a little wood, pure cellulose, and some other substances. It will be worth while now to inquire of what the substances which make up the potato are themselves composed.

Let us begin with wood. Hold one end of a piece of dry white wood in the flame of a spirit lamp till it begins to char, that is, till a black substance appears. You will find that this black substance is so soft and easily powdered that you can write on paper with it, and if you put the

stick into water the black substance does not dissolve in the water any more than the wood itself would do. This insoluble black substance is called *charcoal*. It will also be obtained by burning a hard mass of cotton fibre, which is pure cellulose.

The charcoal is plainly a very different substance from wood, and could not be generally used as a substitute for wood. Whence then did the charcoal come? Hold something over the flame to see whether the charcoal came out of the flame. It certainly did not come from the surrounding air, else our faces would become black with charcoal from the air. The charcoal must have been in the wood at first, but one would suppose that if wood contained so much black charcoal, the wood, instead of being white, would be black or nearly so. Why is it that the black charcoal does not show in the white wood? There must be some other substance in the wood which hides the charcoal from us. Let us try to find what that other substance is.

Heat very slowly a little dry wood, or a ball of cotton wool in the bottom of a test tube, held slantingly and closed with the thumb or with a cork. In either case clear drops of liquid will appear on the glass in the cooler part of the tube. This liquid looks like water, condenses like water, and feels like water. No matter how dry wood is, you can get water out of it by heating it. Of

course you cannot see the water escaping from the wood when the wood is heated directly in the flame, for the water would then pass off into the air as invisible steam. In the test tube, as the steam cannot escape, part of it condenses into liquid water, and so becomes visible. Chemists have found that dry wood and cellulose are made up of charcoal (carbon) and the two gases, hydrogen and oxygen, which compose water.

We cannot prove by our simple experiments that they contain nothing else, but we have found that they contain carbon and the elements of water. We must for the present accept the word of chemists, that there is nothing else in them.

It may seem strange indeed that carbon, familiar to us as black charcoal, and two gases which join to make water, do not make dry wood black and wet. But they are so united that the properties of the product are quite different from those of the substances which compose it. When two substances are so united that they lose the properties which they possess when separate, and their combination takes on other qualities, the substances are said to be *chemically united*, or to be in *chemical union*.

Mix some charcoal and water together in a bottle and see whether they unite chemically. No; the mixture is black like charcoal and liquid like water. In a piece of dried white wood there are just the same elements, but they were chemically united.

Only by burning the wood could the charcoal be separated from the oxygen and hydrogen, which at the same time joined to form water.

When the wood was heated it underwent *chemical decomposition*. If you continue to heat the wood in the closed test tube you may be confused by the fact that the clear liquid water which first appears becomes colored by something which dissolves in the water. This is due to the fact that although cellulose is composed of carbon and the elements of water only, in the process of chemical decomposition new substances are formed from the wood; but these new substances contain nothing which is not in the wood, that is, they are formed from the charcoal, the hydrogen and oxygen in the wood.

Examine dry starch in the same way that you did wood. If it chars you know that it contains charcoal. If when you heat it in a closed tube it yields water, as the wood did, you may infer that, like wood, it is made up of carbon, hydrogen and oxygen. Apply the same tests to sugar, and draw your own conclusions.

Since dry wood, sugar and starch yield charcoal as well as hydrogen and oxygen combined in the same proportions as in water, they are called *carbohydrates*—*carbo* denoting charcoal (carbon), the rest of the name denoting water. It is remarkable that starch, sugar and wood, which

differ from each other in so many respects, should be composed of the same substances. We have seen that the charcoal and the gases which compose water are chemically united in these carbohydrates, for wood, sugar and starch are quite different in their properties from either carbon or water. No one would mistake either of them for carbon or for water.

You remember that we found water and starch in a potato. Were *they* chemically united? No, for the properties of the water were evident in the potato juice, and when we touched the pulp of the potato with iodine solution, a blue color appeared, showing that the starch is not chemically united with anything, else it would not display this property. Besides, we washed the starch out of the pulp, which we certainly could not do if it were chemically united with another substance.

When a substance is not in chemical union with another it is said to be *free* or *uncombined*. The water in potato juice is *free*.

Since wood is made up of substances chemically united, it is called a compound substance, or a *chemical compound*. As no one has been able to find anything in charcoal except charcoal, it does not seem to be composed of two different substances, and it is therefore called a *simple substance* or a *chemical element*.

XV. WHAT BECOMES OF WOOD WHEN IT BURNS

Material.—Wide-mouthed bottles, matches, small sticks and shavings of dry wood, bowls and basins, and a jar. If suitable bottles are not available deep tumblers may be used instead. Lime-water for this lesson should be prepared two or three days in advance, as follows: Soak a lump of lime (quicklime) in water in a bowl, pour off the water which the lime does not absorb. Soon the lime will become quite hot and crumble into a dry powder. This dry powder is water-slacked lime. Put a few tablespoonfuls of the slacked lime into a jar. Fill the jar with water and stir the slacked lime through it. Cover, and set away to settle. When the water becomes clear, test it with litmus paper, to find whether it is acid or alkaline. This clear *solution of water-slacked lime* is called *lime-water*. Cover the jar to keep out the air. Cork up the remainder of the lime in a bottle and save it for use in making lime-water. It will change if you leave it exposed to the air.

Recall the fact that a stick of wood soon burns away in a stove. No wood or even charcoal remains—only a small quantity of gray ash, which is neither wood nor charcoal since it will not burn. What becomes of the wood? Whither does it go?

Set fire to a thin shaving of dry wood; keep it burning without smoke, till the wood and charcoal have all disappeared for some distance from the end. The wood is gone, yet you did not see it going. You saw the flame, but you saw nothing rising out of the flame; nevertheless, some gas, invisible to you, may have been ascending from the flame.

Set fire to one end of a dry stick, not larger than a lead pencil. Hold it so that it will burn with a small smokeless flame below the mouth of a dry wide-mouthed bottle, held inverted over the flame. See the liquid collecting on the inside of the bottle. Feel this liquid with your finger and taste it. Recollect that dry wood is composed of charcoal and the elements in water. *Water* from the burning wood must have risen out of the flame as invisible steam. You could not see the water till the steam condensed into liquid water on the glass. Rinse the bottle, wipe it dry, and hold it again mouth downward over the smokeless flame of a burning stick. In a minute or even less, place the palm of your hand tightly against the mouth of the bottle to keep any gas which may have risen into the bottle out of the flame from escaping, and then turn the bottle mouth up. Partially remove your hand and quickly empty a little clear lime-water into the bottle. Cover the bottle tightly again as soon as the lime-water is in; and shake the lime-water *up and down* through the gas in the bottle. If you do this experiment carefully, you will see a decided change in the appearance of the lime-water.

There must have been in the bottle a gas which produces this effect on the lime-water. This gas was not in the bottle before it was held over the flame, as you can prove by shaking lime-water through

a bottle of air. The gas, therefore, must have risen out of the flame into the bottle. This gas is known as *carbon dioxide*. We can distinguish it from other gases by its effect on lime-water.

When we burn wood, then, we may catch as they ascend from the flame two substances which pass off as gases—water and carbon dioxide. Now wood contains carbon and the gases which combine to make water. This seems to show that the carbon of the wood must be in the carbon dioxide. If this gas were pure carbon it would become solid carbon as it cools, for carbon is solid at ordinary temperatures. So carbon dioxide must contain some other substance than the carbon of the wood; and the carbon in the gas must be chemically united with that other substance, for it has different properties from either. This means that carbon dioxide is a compound substance.

EXERCISES

1. Put some starch in an iron spoon and hold it over the flame of a spirit lamp, till the starch bursts into flame. Then catch the gases which arise from the flame, and find whether they are the same as those which come out of the flame of burning wood.
2. Try the same experiment with sugar.
3. When we burn wood or any other carbohydrate, which of the substances which make up the carbohydrate do we really burn?
4. Why can we not see anything except a little ash in place of the wood which we burn in our stoves?

XVI. WHAT CARBONIC ACID GAS IS COMPOSED
OF—OXIDATION

Material.—Charcoal, crystallized chlorate of potash, black oxide of manganese, lime-water, wooden toothpicks, small hardwood sticks, small squares of window glass, brass wire.

Procure some wood charcoal from a stove or by charring a piece of wood. Wind a piece of brass wire about a piece of charcoal, closely enough to prevent it from falling out. Leave part of the wire projecting for a handle. Shake together in a test tube a few crystals of chlorate of potash and a much smaller bulk of black oxide of manganese. Try a test stick (a hardwood toothpick is just the thing), first merely glowing at the tip, then burning with a flame, in the mouth of the test tube. Note the results, if any.

Heat the mixture with a spirit lamp, till a stick with a glowing tip will burst into flame when held in the mouth of the tube. Hold the tube away from the lamp and repeat the experiment until the stick will no longer burst into flame.

This gas cannot be air, for the glowing stick does not act in that way while it is in the air. This gas in which a stick burns so much faster than in air is called *oxygen*. Oxygen is another substance which has never been broken up into two different substances, and so is classified as a *simple substance* or *chemical element*.

Add a little more chlorate of potash to the mixture in the test tube. Insert the mouth of the test tube into the mouth of a small wide-mouthed bottle held with the mouth turned obliquely downward, and apply heat to the tube till a glowing stick will promptly burst into flame when held in the mouth of the *bottle*; then quickly cover the mouth of the bottle with a wet piece of glass. Heat the prepared charcoal till part of it is glowing. Hold it for a moment in the air; then lower it into the bottle of oxygen, allowing a piece of cardboard, through which you have passed the handle of the wire, to close loosely the mouth of the bottle. Note whether the charcoal becomes hotter or colder, when put into the oxygen, and whether it glows more or less brightly than before.

Take the wire with the remaining charcoal in it out of the bottle; and quickly, before the gas in the bottle has had time to mingle with the air outside, shake a little clear lime-water through it. The apparent change in the lime-water will convince you at once that carbon dioxide was formed by burning the charcoal in the oxygen.

If necessary, repeat the experiment to make sure whether the charcoal was disappearing as the new gas was being formed. You should explain, too, why the charcoal stopped burning. Since it was not for lack of charcoal, it must have been for lack of oxygen.

Now we must enquire what the carbon dioxide is composed of. It cannot be carbon in the form of gas, for if it were, it would become a solid as soon as it cooled down to the ordinary temperature. Neither is it something contained in the carbon, for charcoal is a simple substance. As oxygen is also a simple substance, the carbon dioxide could not have come from the oxygen. Since it is neither carbon nor oxygen, nor a part of either, it must be formed of the two chemically united together. This is made the more certain by the fact that both the charcoal and the oxygen were gradually disappearing in the bottle at the time the carbon dioxide was being formed. They were evidently disappearing by entering into chemical union, when a new substance with different properties from those of either was formed. Because this gas is made up of oxygen and one other simple substance it is called an *oxide*. As it contains two parts of oxygen to one of carbon it is called *carbon dioxide*. When carbon or any other substance unites with oxygen it is said to *oxidize* or undergo *oxidation*.

But how can we account for the charcoal becoming so hot while the oxidation was going on? It must be that the chemical union in some way produced or caused the heat and the bright light, for as soon as the oxidation ceased, both the heat

and the light disappeared. Heat so produced may be called *heat of chemical union*.

EXERCISES

1. Put some lime-water into a small bottle and blow your breath through it by means of a tube till you get a decided effect. Argue from this experiment that carbon is oxidized in the body.

2. In what part of the body does the oxidation of carbon take place and at what temperature?

3. Find whether charcoal can be oxidized at this temperature outside of the body.

4. Where and how is the charcoal oxidized in the body taken in? How often?

5. Where and how is the oxygen, used in the body for oxidizing carbon, taken in? How often?

6. Prove by experiment that both vegetable food and animal food contain carbon.

7. Mention a case in which the oxidation of carbon produces heat without light.

XVII. THE COMPOSITION OF THE AIR

Material.—Wide-mouthed bottles, dry pieces of wood, lime-water, a pitcher, tumblers or bowls, snow or ice, salt.

Burn without smoke for less than a minute the charred end of a dry stick in a bottle full of air. Remove the stick quickly, pour a little clear lime-water into the bottle, close its mouth with your hand, and shake the lime-water *up and down* through the bottle. You can tell by the result

that carbon dioxide was formed by burning the charcoal in the bottle.

Now that gas, as we found before, is a compound gas, made up of carbon and oxygen chemically united. The stick supplied the carbon (charcoal), but whence came the oxygen necessary to unite with the carbon? The carbon of the stick must have obtained the oxygen from the air which surrounded it; hence the air must contain *oxygen*.

The air, however, cannot be pure oxygen, else a glowing stick would burst into flame in the air as it does in oxygen. There must be some other gas mixed with the oxygen in the air—a gas which does not allow a stick to burn in it, for it prevents things from burning as rapidly in air as they would in oxygen. The gas which does this is *nitrogen*.

Notwithstanding the nitrogen in the air, the oxygen united with the burning charcoal; the nitrogen too displayed its own properties, by hindering the combustion. Since the oxygen and nitrogen in the air do not conceal each other's properties, we may conclude that they are not chemically united, but are merely intermingled.

Let us seek for other gases in the air. Look for water first. Fill a pitcher with water at the temperature of the room; no water soaks through or collects on the outside of the pitcher. Fill the pitcher with a mixture of snow or broken ice and

common salt. Water does collect on the outside of the pitcher. As the water could not soak through the sides of the vessel it must have come out of the air around the vessel; therefore the air of the room must contain water, but that water must exist in the air as an invisible gas, for we cannot see it till it condenses into a liquid. This invisible gas is in fact *steam*.

We shall next test the air for carbon dioxide. Shake lime-water through a bottle of air. The water remains clear. At first you are inclined to decide that the air contains no carbon dioxide; but this experiment only shows that there is not enough carbon dioxide in a bottle of air to have any visible effect on the lime-water. If the lime-water were exposed to the open air for a longer time there might be a perceptible effect.

Fill a tumbler or bowl half full of lime-water and leave it exposed to the air. Do not disturb the lime-water for some days, but look at it occasionally. You will observe a scum gradually forming on the exposed surface of the liquid. Since this scum only forms where the liquid meets the air, it must be caused by something in the air. Now we know that carbon dioxide acts on lime-water when mixed with it. To decide whether it is carbon dioxide in the air which caused the scum to form, put some lime-water in the bottom of a deep, wide-mouthed bottle. Burn a charred stick

in the bottle above the lime-water for a short time and quickly cork the bottle, or cover it with a slip of glass which has been smeared with vaseline, so that it will not let the gas escape from the bottle. Notice whether the scum forms more or less slowly than it did when the lime-water was exposed to the open air. Repeat the experiment if necessary. I think you will be able to show from this experiment that the air contains a small proportion of *carbon dioxide*.

We have now found four gases in the air. Other gases exist there in small proportions, but we cannot find them at present.

EXERCISES

1. Show whether nitrogen has any visible effect on lime-water.
2. Mention three gases in the air, in neither of which, when pure, will a stick burn.
3. When charcoal burns in the air, with which of the gases there does it unite? Why does it not unite with one or more of the others?

XVIII. THE COMPOSITION OF WATER

Material.—Small pieces of zinc (granulated zinc is best), hydrochloric acid, test tubes, delivery tubes with corks or rubber stoppers, tumblers or wide-mouthed bottles. If delivery tubes are not available, the following experiments can be performed without them. By generating the gas in small bottles, even test tubes may be dispensed with.

Put small pieces of zinc to a 1/4 pth of an inch

into a test tube. Add enough dilute hydrochloric acid to cause an active bubbling (effervescence). Insert a cork through which passes a delivery tube of $\frac{1}{4}$ -inch bore. Hold a small wide-mouthed bottle inverted over the mouth of the tube to catch the gas as it issues. In about a minute, hold the bottle a short distance away from the tube with the mouth still turned downward, and set fire to the gas you caught in the bottle. Repeat the experiment till you see how fast the gas burns, and note the color of the flame. Turn the mouth of a bottle full of the gas upward at once, and find whether the gas will stay in the bottle till you set fire to it. Show that this gas is neither oxygen, nitrogen nor carbon dioxide. This combustible gas is called *hydrogen*, and like oxygen and nitrogen it is a simple substance.

We should next try to find what becomes of the hydrogen when it burns. Pour the liquid off the zinc in the test tube. Add acid as before. Insert the cork with the delivery tube and set fire to the hydrogen as it issues from the tube. Can you see anything issuing from the flame of the burning hydrogen? Hold a dry tumbler mouth downward just above the flame till a liquid condenses on the inside of the tumbler. Examine this liquid by taste and touch. How do you account for the fact that you did not catch any hydrogen in the tumbler?

Since water is the only substance we can find coming out of the flame in which the hydrogen is burning, we must conclude that water is the only substance which is produced by burning hydrogen in the air. We have found that when carbon burns in the air it unites with the oxygen there to form carbon dioxide, so it is highly probable that when hydrogen burns in the air it also unites with the oxygen in the air to form an oxide of hydrogen. As water is the only substance we found arising from the flame, we must conclude that water is this oxide of hydrogen and is composed of hydrogen and oxygen in chemical union. Hereafter, then, we must remember that water is *hydric oxide*; but we shall still continue to speak of it by its familiar name.

EXERCISES

1. Why can you see nothing coming out of the hydrogen flame?
2. Explain why water and carbon dioxide will not burn.
3. Explain how water extinguishes a fire.
4. What is really happening to a house when it is on fire? What invisible products are going off into the air from the fire?
5. Note whether solid sulphur, without heating or rubbing, has any smell, and try whether it is soluble in water. Burn a little sulphur without smoking, and find whether any gas comes out of the flame. How is this gas easily detected? Argue out the composition of this gas. It is called sulphurous acid gas. Shake a little water through a bottle containing the gas and test the solution with litmus paper.

XIX. AMMONIA GAS AND ITS COMPOSITION

Material.—Tumblers, test tubes, spirit lamps, small bottles, saucers or large nappies, litmus paper, water, lime (unslacked), sal ammoniac.

Mix in a dish about equal volumes of sal ammoniac and powdered lime (quicklime). Can you smell or see anything coming off from the mixture? The pungent gas which is set free by lime from the sal ammoniac is called ammonia gas.

Put a teaspoonful of the mixture into a test tube, and apply heat slowly. Do not make the mixture hot enough to smoke. Catch the ammonia—which is now set free more rapidly—in a small bottle, held so that the mouth of the test tube just enters the mouth of the bottle. In a minute or two, set the bottle, mouth down, in a shallow dish of water. Shake the bottle without lifting its mouth out of the water. The water should rise until it fills, or partly fills, the bottle. Test the ammonia still escaping from the test tube, with litmus paper, to find whether the ammonia gas is acid or alkaline; also try to set it on fire with a match. Turn the bottle mouth up, without losing the water which rose into it; taste the solution in the bottle, and test it with litmus.

You have illustrated in these experiments several properties of ammonia gas, but you have not found

what the gas is composed of. We cannot prove that by means of the simple apparatus we are using, so we will have to accept, without verification, what the chemists say about its composition. This is regrettable, but it is the best we can do at present.

Chemists have found that ammonia is a compound gas composed of two other gases, with both of which we have met, viz., *nitrogen* and *hydrogen*. We found nitrogen in the air some time ago, and we prepared hydrogen quite recently and found it to be one of the elements of water.

EXERCISES

1. Compare ammonia with each of the two gases of which it is composed. What does the fact that it differs so much from them indicate?
2. Try whether water will rise into a bottle of air when stood mouth down in water, as it does into a bottle containing ammonia gas. Explain the result.
3. Why did the water rise higher in some of the bottles containing ammonia than in others?
4. What became of the ammonia gas when the water rose into the bottles? Give reasons for your answer.
5. Show whether there is much ammonia in the air.
6. Show whether ammonia is an acid or an alkaline gas.
7. Since lime contains neither nitrogen nor hydrogen, what can you prove, from your experiments, about the composition of sal ammoniac?
8. Show whether sal ammoniac contains anything besides ammonia gas.

XX. WHAT THE GLUTEN OF WHEAT IS COMPOSED OF

Material.—Powdered starch, wheat flour, dried gluten and beans; powdered lime or *dry*, water-slacked lime; litmus paper, red and blue, test tubes and spirit lamps; some simple contrivance for pulverizing the gluten and beans.

We shall first try whether lime will act on starch and gluten as it did on sal ammoniac. Rub lime on damp red litmus paper and note the visible effect. Put about $\frac{1}{2}$ of an inch of powdered lime into a test tube. Add as much powdered starch as could be piled on a five-cent piece (or about the bulk of a pea), mix the lime and starch well together by shaking the tube. See that no lime is sticking to the glass in the mouth of the tube. Heat the mixture while you hold a strip of damp red litmus paper in the mouth; note the smell of the escaping gases, and whether there is any change in the color of the litmus paper. If no change appears, try damp *blue* litmus paper.

Repeat the preceding experiment, using powdered gluten instead of starch. You will find that an alkaline gas is set free by the lime, as when sal ammoniac was heated with lime. *That gas was ammonia*; it is likely then that this gas is the same. The odor of the ammonia may be disguised by the smell of other gases set free at the same time.

As no ammonia was set free when we used

starch, we must infer that the ammonia was set free by the lime acting on the gluten; therefore gluten must contain nitrogen, for ammonia contains nitrogen.

Try whether dried gluten will char. This is a test for carbon.

Besides carbon and nitrogen, gluten has been found by chemists to contain hydrogen, oxygen and a little sulphur—that is, it contains the three elements which make up the carbohydrates and two others—nitrogen and sulphur. We have proved that gluten contains carbon and nitrogen, but we cannot prove at present that it contains the other three elements.

The “gluten” is composed of several proteins mixed together. These proteins are compounds much more complex than the carbohydrates. Some, like one found in the potato, are soluble in water, others present in the gluten of wheat are insoluble in water.

They are often spoken of as nitrogeneous compounds, because they differ from the carbohydrates in containing nitrogen. Recollect here that nitrogen is that gas mixed with oxygen in the air which dilutes the oxygen to such an extent that a glowing stick will not burst into flame in the air. Indeed it has been proved that about four-fifths of the air is nitrogen.

EXERCISES

1. Pulverize a well-dried bean, and test it for proteins by heating a mixture of the powdered bean and lime, and making the litmus test as you did in the case of gluten. You may be able to get the damp red litmus paper to turn blue without using the lime, but the color will soon change again. The principal protein in beans is called *legumin*. This name is taken from the word *legume*, which denotes a pod, such as that of a bean.

2. Test sugar for nitrogen in the same way as you did starch and gluten. If the gases set free have no effect on the color of red litmus paper, try blue litmus.

3. Find whether Indian corn meal contains gluten or other proteins.

XXI. VEGETABLE OILS AND ACIDS AND A SALT

Material.—Grains of corn soaked till quite soft, olive oil or some other vegetable oil, pieces of thin, white writing paper, litmus paper, sour fruits, starch, cotton wool, sugar, water-slacked lime, spirit lamps and test tubes, enamelled plates.

Oils. Look at a grain of soaked corn and you will observe, showing through the seed-case on one side of the grain, the outline of a body perhaps about one-fourth of an inch long and in shape resembling the half sole of a boot. Open the grain and take this body out. It is quite thick, and you will recognize it as the part of the grain which grew into the young plant at germination. It is, therefore, often called the *germ* but it really is an embryo. Remove several of these embryos from the grains, dry them, and examine them for oil.

Place a drop of olive oil or any other vegetable oil on a piece of thin writing paper, and hold the paper between you and the window. The oil spot on the paper will become nearly transparent. As olive oil is a fixed oil, the spot will remain indefinitely.

Crush two dry embryos of Indian corn and place the fragments on a square slip of white writing paper. Lay the paper on an enamelled plate, and heat the plate slowly over a lamp or on a stove or radiator, taking care not to burn or char the paper. Press the fragments against the paper. In a short time you should get a clear spot on the paper resembling an oil spot, and permanent like it.

The oil spot can be obtained without heat by covering the fragments of the germs with a few drops of benzene. The benzene will dissolve out the oil which will leave a spot on the paper after the benzene itself has evaporated. But benzene is such an inflammable substance that it is not safe to use it in a school. Gasoline and ether will also dissolve oil, but they too are very inflammable.

Mention other plants which store up oil in their seeds or fruits.

Put a few drops of a vegetable oil into a teaspoon and hold the spoon in the flame of a spirit lamp until the oil takes fire. It will burst into flame sooner if you tip the spoon a little, so

that the hot oil will approach the edge close to the flame. Hold a wide-mouthed bottle, mouth down, over the flame. Feel the liquid which gathers on the inside of the bottle.

Catch in the bottle the invisible gases escaping from the flame. Place your hand promptly over the mouth of the bottle, and shake a little lime-water *up and down* through the bottle while still keeping it closed with your hand.

You should now be able to prove that both water and carbon dioxide rise from the burning oil. But when a substance is burning in the air—as we have shown before—it or some substance in it is uniting with the oxygen of the air. Now what substances must the oil contain in order that water and carbon dioxide may be formed by burning it? Water is formed by hydrogen uniting with oxygen, and carbon dioxide is formed by carbon uniting with oxygen; hence the oil must contain carbon and hydrogen.

We cannot prove that the oil contains oxygen, for when a substance is burning in the air it is taking oxygen *from the air*. Chemists tell us, however, that most oils contain some oxygen, but not so much as carbohydrates do. It seems, then, that vegetable oils contain the same elements as the carbohydrates, but in a different proportion.

Acids. Heat a bit of starch in a tube, closed with

your thumb, until gases with a strong smell are given off. Then put a piece of blue litmus paper into the tube. The effect will show that an acid has been formed. Now since the acid has been formed from the starch, it is evident that the acid contains no other elements than those of starch—viz., carbon, hydrogen and oxygen. We have not proved, of course, that it contains all of these, and will therefore be compelled to accept that conclusion on the authority of chemists.

Cut slices off several sour fruits, and press a piece of blue litmus paper against the juicy pulp. You will find that the effect indicates an acid in each case. The sour taste common to all of these fruits must be due to the presence of the acids, so we may consider a sour taste as good an indication of an acid as the litmus test. The principal acid of the apple is called *malic acid*, from the Latin word "*malum*," which denotes an apple. The distinctive acid of the lemon is called *citric acid*. These acids are also found in other fruits, but there are many different vegetable acids.

Find whether the two other carbohydrates you have met with—sugar and cellulose—yield acids when heated in a closed tube. You may use cotton wool, as it is pure cellulose.

A Salt. Squeeze the juice out of half a lemon. Taste it and test it with litmus paper. To what is

the taste and the action on litmus due! Taste water-slacked lime, and test it with damp litmus paper. The taste and the effect on litmus indicates that water-slacked lime belongs to the class of substances called *bases* or *alkalies*. Their action on litmus is just opposite to that of an acid.

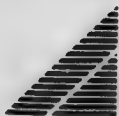
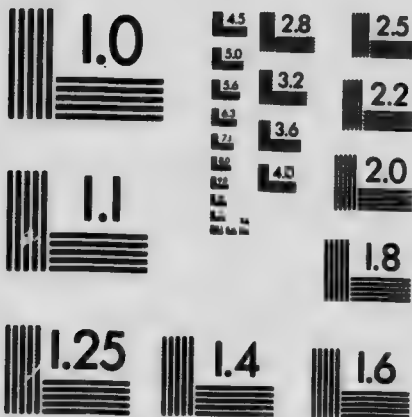
Stir water-slacked lime into the lemon juice, a little at a time, until the liquid will neither turn blue litmus red nor red litmus blue, or at least very slowly, and till the liquid has neither a sour nor an alkaline taste. Dilute with water, if necessary. Set the dish over the flame of a spirit lamp, or on a hot stove or a radiator, until the water has evaporated.

The dry residue which remains in the dish is called a *salt*. This is a salt of citric acid, because that acid was mixed with a base to produce the salt. The name of this salt is *citrate of lime*. You can see that this name is formed from the names of the acid and base which were mixed to produce the salt.



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XXII. TREES IN WINTER

Material.—Small branches from various trees, jars or large bottles containing water, tincture of iodine, spirit lamps.

It is now past midwinter and the trees have been exposed for many weeks to all the severities of our northern climate. Let us examine branches of some of them, and try to learn what the trees have been doing, or whether they have simply been "standing it" till spring should arrive.

You can readily tell whether the branches have grown any longer or the buds any larger than they were in the autumn. It will be interesting to try whether the dormant buds can be got to develop at this season, several weeks sooner than their usual time. If we place them in spring conditions will they respond as though it were really spring? Let us try.

Set a few branches from neighboring trees—willows, poplars, apples, etc.—in jars or bottles of water, and stand them in a warm, sunny room at home or in the school building. Change the water occasionally, and note any signs of life which become apparent in the buds.

Bring in fresh branches from time to time, and remove from the water those which fail to show a satisfactory response to the new conditions. Before long some buds will begin to develop.

Note whether the bud-scales leave any marks or scars behind them when they drop off, and watch to see what each bud becomes. Especially observe whether a leaf-bud simply develops into a leaf or into a branch bearing one or more leaves. Count the number of leaves which appear on the branch which develops from one bud.

Some of the buds may develop into short branches bearing flowers or flower-clusters. A *leaf-bud* develops into a branch bearing one or more foliage-leaves; whereas a *flower-bud* or *fruit-bud* becomes a short branch, bearing one or more sets of flower-leaves, sepals, petals, stamens, carpels.

A flower, then, with its stalk may be regarded as a branch whose leaves are usually grouped close together upon a short stem forming whorls closely set one above the other, and arranged so that they can in different ways join in helping to reproduce the plant.

In watching the growth of the bud, you should not fail to notice whether the leaves *grow*—from little leaves when they first appear to be large leaves—or whether they merely unfold.

Record the date at which some particular bud begins to swell. In two or three weeks measure the length of the new branch into which it has grown, and calculate how much it increased in length, on an average, in one week—in one day—in one hour.

EXERCISES

1. Early in the winter we may begin to test the branches and buds of trees, to find whether there is any food stored in them to nourish the buds in spring when they begin to grow, and to assist in the formation of new wood and bark in the older parts of the branches and in the main stem. Cut off short pieces from the branch; split them and test them for starch and sugar. Test the buds themselves as well as the stem for stored food.

2. Near the close of the winter, but before the buds begin to swell, you may find signs of activity in the main stem and branches. Pull off some of the bark and test the juicy layer under it by taste, and in other ways. This part of the stem and its branches is called the *cambium layer*. Examine it and other portions of the stem again later in the season, and try to find what becomes of the food materials you found.

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JUNCO.



AMERICAN
GOLDFINCH.



SONG-SPARROW.



VESPER SPARROW.



PHOEBE.



TOWHEE.

From "Birds of Canada."—NUTTALL. (Reproduced by permission.)

SPRING LESSONS

XXIII. THE RETURN OF THE BIRDS

At the first indication of the approach of spring you may be on the watch for the return of the earliest of the feathered songsters who last autumn were impelled southward by a strong impulse which nearly all our wild birds feel and must obey. While yet the snow overspreads the fields, except in a few favored spots, we may wake any bright morning to hear again the sweet note of the Song Sparrow, the more monotonous measure of the Junco, or the cheerful song of the American Robin. As the days lengthen, and the sun's heat melts the snow and releases the ice-bound streams, more species continue to arrive, each with its distinctive song, plumage and habits of life.

I am sure that it will add much to the pure and simple pleasures of your lives to learn the songs of the birds—not perhaps well enough to sing or whistle them—but at least to print them on your memory so clearly that you can recognize all the commoner birds by their notes.

The marked differences in the plumage, size and habits of the species will soon enable you to distinguish those which frequent the near-by fields,

trees and waters. Of course these are not all birds of song, but all have their peculiar calls and cries. The school library should contain a good book on birds, with descriptions of the species which may be found in your region; and there may be a bird lover in your neighborhood who is sufficiently well acquainted with birds to give you their names from your descriptions. If these means fail, the descriptions may be sent to some authority on birds, who will be glad to send you their names. Be careful, however, to give descriptions which bring out the distinctive characteristics of each species.

But let me beg of you not to shoot the bird to settle the question of its name. It is far better that you should never know the name than that you should take its innocent life. Close observation and patient waiting will be rewarded in nearly every case by the discovery of the bird's identity; and, if not, the training will be good for you, and help to make you keener of eye and steadier in purpose.

As spring advances, you will find great delight in watching the happy and industrious home-life of the birds which build their nests in your neighborhood. You can induce many birds to set up housekeeping close to your home and your school, by providing nesting-places for them in the way of little houses made of old boards or pieces of

hollow logs set up on tall poles. You may attract many birds too, by planting trees and shrubs which yield fruits agreeable to the birds. A shallow dish set on top of a pole or on a shelf outside your window, and supplied with water occasionally, will be a great convenience to birds as a place for drinking and bathing.

Every day you will learn something new about their ways, as you watch them making their nests, hatching their eggs, and feeding their young; and you will find that nearly all these birds feed mainly on the seeds of weeds, or else upon the various forms of insect life. Birds thus render a service to the country which can only be stated in millions of dollars. Were it not for the birds, destructive insects would certainly multiply so rapidly that the annual loss, due to their ravages upon our crops, orchards and forests—which is now very great—would be vastly increased.

It is true that sometimes a flock of birds will make a run upon a cherry tree or a grain field, and may thus cause loss to a single person, although the species in the long run may be worth much more to the country than it costs. The English Sparrow, however, is one bird for which little defence can be made. I can only ask that, in destroying these sparrows by poisons or otherwise, care may be taken not to destroy useful or harmless birds of other species.

Allowing for such rare exceptions, let us all do our part to protect and encourage bird life. We can thus render valuable service to our country, while at the same time the simple and gentle lives of the birds will help to sweeten our spirits and divert our thoughts from the cares and worries which even children sometimes feel. Our ears will gradually become more sensitive to the birds' songs and other soothing influences of nature through which the kind Father of all life would speak peace to troubled hearts.

In the spring-time, too, many wild things, from the clumsy toad to the graceful deer, which have solved with more or less success the problem of existence in the winter without migration, will emerge from retirement to play their parts in the drama of life. Let me bespeak from you a generous treatment of these defenceless wild creatures. The world would be a much less interesting home for man without them. We want our country to be well cultivated and productive, but we can surely spare a little space and a little food for our lowlier brethren of the wild.

"He prayeth best who loveth best
All things, both great and small ;
For the dear God who loveth us,
He made and loveth all."

XXIV. THE SEED AND THE LITTLE PLANT WITHIN IT

Material.—Flower-pot saucers, table plates, pieces of blotting paper or flannel, flower-pots, shallow wooden boxes, garden soil, a collection of seeds—some large and some small, including beans and grains of corn.

In the latter part of March or early in April, soak a few beans and grains of corn, and place them between damp pieces of blotting paper or of woollen cloth in a flower-pot saucer or table plate, and cover the whole with a shallow dish inverted over the cloth or paper. Record the number of each kind of seed used, so that you can calculate the percentage of good seeds. Keep the dishes in a warm place and add water from time to time to keep the paper or cloth moist.

When you find the seeds are beginning to germinate, soak some more beans and grains of corn for a day or two, until the seed-coat or seed-case can be easily removed from the seed. Examine the germinating beans to see at what point the root-end of the growing plant emerges from the seed-coat. Find the same place in a dry bean.

When the young bean plant has entirely escaped from the seed-coat, examine it again with care. It should have a pair of thin veiny leaves, a short stem upon which these leaves grow, a pair of thick, fleshy organs below the pair of thin leaves,

and a continuation of the stem below these, terminating in a root-like part. The two fleshy organs grow on the same stem-like part as the two thin leaves, so we must classify them also as leaves—the first or lowest pair of leaves. The root-like part of the little plant will soon bear root-hairs. We have here then a complete plant with all the organs of vegetation—stem, leaves, and root with its root-hairs.

Now remove the coat from a recently soaked bean, taking care not to break or injure anything inside the coat. Note that the body which you have left in your hand, after removing the coat, has all its parts connected together. You will find the two thick leaves connected by a short stem which ends in an undeveloped root bent up against their edges. Part them slightly or break one of them off, and you will find a little bud with two thin leaves lying in a slight hollow between the thick leaves. So we have found in the seed of the bean, before germination has begun at all, a complete but undeveloped bean plant, with a stem bearing four leaves, and at the lower end of the stem the beginnings of a root.

This little plant contained in the seed is known as the *embryo*. The two thick leaves so laden with nourishment that they seem most unlike ordinary foliage leaves, are called the *seed-leaves*, because they are the first and principal leaves of the

embryo. The two thin leaves are not called seed-leaves, although they also are leaves of the plantlet. From their resemblance to a little plume, they, together with the growing point between them, are called the *plumule*. There are two leaves then in the one plumule.

It is clear that the seed of a bean is made up of two parts—the *seed-coat* and the embryo which fills the seed-coat, and that the plantlet is made up of *four* leaves and the *axis* to which they are attached. This axis—as it appears before germination—is almost entirely a stem bearing the four leaves, the lower end or radicle not having yet developed into an evident root.

In a former experiment we found a carbohydrate (starch) and a protein (legumin) in a bean seed. These two substances must be mainly stored up in the thick seed-leaves of the seed plantlet. This would seem to account for the rapid growth of the plantlet at first.

Set out some of the germinating beans in a good soil in flower-pots or boxes. Keep them warm and moist and watch their continued growth. Also plant some dry beans.

Examine a soaked grain of corn as you did the bean. Remove the little body lying in one side of the grain—the body which you know as the *germ*. It is harder than the rest of the soaked grain, not having absorbed water so freely. Com-

pare it with the young corn plant you obtained by germination.

It will soon appear that this so-called germ is a little corn embryo. The slender, straight, stem-like part which lies in the middle of the flatter side of the germ is the *axis*, at the top end of which is the plumule, while from the lower end the root strikes out. The broad, fleshy part of the embryo is the *seed-leaf*, corresponding to one of the thick leaves of the bean embryo.

The plantlet of Indian corn has but one seed-leaf, and its plumule shows at first to the naked eye no distinct leaves to correspond with the two leaves of the bean plumule. In the bean, the plantlet fills the seed-coat, so there is no food stored in the seed outside of the embryo; but in the grain of corn the plantlet occupies only the smaller part of the grain. Examine the large mass of stored food which fills the interior of the grain outside of the embryo. A great part of it is floury, white and opaque because it is largely starch. But just below the coats of the grain is a transparent horny region rich in gluten.

You will recollect that we found some time ago that the germ of Indian corn contains much oil. This is food stored up in the embryo.

Plant grains of corn in pots or boxes of earth, and follow the development of the young plants for several weeks

The seeds of clover, turnips, etc., are so small that you cannot without a magnifying glass see plainly the little plants in them. This difficulty is easy to overcome. You have only to place the seeds in conditions favorable to germination, when the embryos will burst the seed-coats, and will soon be sufficiently large for you to see them and their organs quite plainly.

Compare these little seedlings with those of the bean and the Indian corn, and note whether they have one or two seed-leaves; also observe in which of them the new leaves are arranged in pairs, and in which they are alternate, one above another.

From these studies we must conclude that every perfect seed contains a little plant and that the parent plant lays up a store of food for the plantlet, either in the embryo itself or in the seed outside of the plantlet, or in both situations. It is now plain that it is not the seed which grows but the little plant within the seed.

EXERCISES

1. Grow in pots or shallow boxes, from tested seeds, some of the common garden plants, such as tomatoes, cabbages, lettuce, cucumbers, pansies, asters, etc., to be set out in the school or home garden.

2. Place some potato tubers in a dark warm closet or box (to represent a cellar); others in a warm room exposed to the sunlight. In two or three weeks inspect them, and decide from the results which is the better way of sprouting potatoes for early planting.

XXV. THE SEASONAL CHANGES OF SPRING— SPRING CALENDAR

As soon as the first returning bird appears you should begin a Nature Calendar for spring. In it record the various events and changes which mark the approach and progress of spring.

The birds and flowers of spring will be especially attractive to nearly everyone. In early spring many birds frequent the trees and fields near our homes for a while before they set up housekeeping in woods and retired places.

In many parts of the country the groves and forests are veritable flower gardens during the greater part of the month of May. Any one who has any appreciation of natural beauty should delight to learn something of the habits of these wild plants of spring, and find out their names. I hope, however, you will not pull them up ruthlessly, but spare them to beautify the earth for succeeding generations. I am moved to remind you of this, because already in some districts—especially in the vicinity of towns and villages—

all these beautiful plants have been practically exterminated.

I shall enumerate here some of the features of the spring-time which are worthy of notice and of record in your calendar: The change in length of the shadow of some definite object—to be recorded once every few weeks at the same hour of the day; the temperature of the air at a certain hour—entered once a week; the length of the day (from sunrise to sunset) as recorded in the almanac—once a week; the disappearance of snow from the fields and ice from the streams; sudden changes of weather; the first appearance of different species of migratory birds, the dates of their nesting, and the period of hatching; the time when sap begins to run in the trees, and the buds to swell; the dates of the blossoming and leafing of the trees and shrubs in woods and orchards; the blooming of early spring flowers; the dates of sowing the different garden and field seeds, and the first appearance of the plants above ground; what kinds of plants suffered from spring frost, with dates.

EXERCISES

1. How much longer is the time of daylight (from sunrise to sunset) on June 1st than on April 1st?
2. How much longer or shorter is your shadow at noon on June 21st than on March 21st? Account for the fact.
3. How do you explain the gradual rise in the temperature during the spring months?

4. How is it that the buds of trees and the early flowering plants can develop so rapidly in spring, while the soil is yet quite cold?
 5. What trees or shrubs were in bloom on the day you sowed your first carrots, beets, peas, corn?
 6. What trees in your neighborhood blossom before their leaves expand?
 7. Find one or more trees (or shrubs) in which the pollen-bearing flowers (staminate flowers) and the seed-bearing flowers (pistillate flowers) are in separate clusters on the same tree, and one or more in which they are in separate clusters on separate trees.
 8. Find, by observation, when the trees are in bloom, whether their blossoms are pollinated by insects, or whether all trees depend on the wind to convey pollen from the stamens to the pistils.
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XXVI. THE SCHOOL GARDEN

School gardening is gradually becoming a very useful feature of school life. It affords an agreeable change from the book and desk work which prevails throughout the cold months. The knowledge and training to be gained in the school garden is certainly no less healthy and useful than the results of the indoor studies. So I hope your school, if it is not already provided with a school garden, will make a beginning this spring, if only with a small plot a few square feet in area.

As soon as the soil is dry enough, have it thoroughly cultivated with plough and harrow, or else with a spade and rake. A sufficient quantity

of good old manure should be worked in at the same time, and the rootstocks of couch-grass and other weeds carefully removed.

If the garden area is large enough, the ground should be laid out in plots upon some definite plan. Four feet by eight or ten feet is a good size for single plots to be cultivated by individual pupils; but if the space is quite limited, several pupils may undertake the joint cultivation of one plot. Walks at least two feet wide should be left between the plots.

Flower seeds may be sown at the ends of the plots with vegetables between, or the flowers may be grown in separate plots, with the vegetable plots arranged symmetrically about them. Perennial flowering plants may be grown along the borders of the garden, or in central or corner plots. The arrangement of the plots and plants, however, should be determined by the tastes of the gardeners, and the size and shape of the ground.

As a rule, the plots should not be raised much above the level of the walks. The soil, particularly near the borders of the plots, does not become so parched during drought under level culture.

The catalogues issued by seedsmen will give the necessary information as to the time for sowing the seeds of different plants, the depth and distance of sowing, and so forth. The larger seeds as a rule should be covered more deeply than small ones.

The very smallest ones may be sown on the surface, and thinly covered by fine soil sifted over them by hand.

The soil immediately above the seeds, but not between the rows, may be pressed down with a narrow board or with the back of a hoe. This brings the soil into close contact with the seeds, so that they can draw moisture from it more readily.

Soon after the garden seeds are sown, wild plants—weeds—will begin to appear, perhaps before the seeds you sowed have germinated. These weeds, if allowed to grow, will rob the garden plants of food and water, cut off much of the sunlight and hinder the circulation of the air. You can easily show the effect of weeds by allowing them to grow in a small plot in which garden seeds have been planted.

The weeds are easily kept down if they are never allowed to make much headway. Go over the soil between the rows often with a hoe or rake. This frequent cultivation will root up the weeds that have come up, and bring many that are just germinating to the surface, where they will dry up and die. If the spaces between the rows are as wide as a narrow garden rake, or wider, the soil between the rows can be cultivated very rapidly with a rake to the depth of two or three inches. Some of the weeds in the rows may be taken out

with a hoe or a weeder, but some of them must be removed by hand.

Thin the garden plants out to the proper distance apart as soon as they are large enough. Some vegetables may be only partially thinned at first, and when large enough for table use, part of them may be taken for food, leaving the intermediate plants to grow.

The frequent stirring of the soil with hoe or rake serves another purpose quite as important as the killing of the weeds. The loose layer of earth formed by raking or hoeing the soil hinders the water from escaping from the soil underneath, and keeps it there to be absorbed by the tiny rootlets by means of their root-hairs.

Were it not for the loose earth mulch formed by the rake, the water would evaporate into the air so fast that the soil about the roots would become very dry and the plants would suffer greatly from want of water, and of course would be retarded in their growth. To demonstrate this, keep a small plot free from weeds, but do not cultivate it at all. Compare the growth of the plants in this plot with those in a well-cultivated plot close by. We shall try to explain later how the loose earth mulch hinders the water from evaporating from the soil below.

The stirring of the surface soil answers the same purpose as watering, so that we may be said to

water the garden with the hoe or rake. Indeed, if we stir the surface once or twice a week, there will be little or no need for watering, unless the weather is exceedingly dry.

If any of the seeds fail to grow, sow others in their places. If early vegetables are used before midsummer, a second crop may be grown on the same ground; in this way all the available area will be occupied throughout the season.

If any of your plants are attacked by insects or diseases, try to find by inquiry or by consulting books or agricultural bulletins the proper remedies, and apply them in good time. Above all, keep your garden free from weeds to the very last.

If you thus tend your garden during the spring months, and arrange for its cultivation during the summer vacation, you will be surprised and fully rewarded to see how the plants have responded to your care—each kind in its own way. Your garden before summer has ended will be a mass of verdure and bloom, delightful to look upon. You may gather from your plot fresh juicy vegetables for the home table or that of a neighbor who has no garden, and flowers for a friend or for a poor invalid who would be helped by your sympathy expressed in this practical way.

In the autumn, after the crop has been removed, the garden should be manured, and either ploughed or spaded to a sufficient depth.

Window and Flower-Pot Gardening. In case your school has no ground available for a garden, not even for a class plot, you will have to confine yourselves to window and flower-pot gardening. Much interesting and instructive work can be done in window boxes, or in flower-pots set on cheap stands. Bulbs and other flowering plants and ferns may be grown, and will add greatly to the attractiveness of the school-room and hallways. Specimens of grains and of the common garden vegetables should be grown also. Much may be learned about their habits and capabilities by varying the conditions of light, heat and moisture.

XXVI. THE MAKING AND TRANSFERENCE OF STARCH IN PLANTS

(For a bright warm day in the latter part of May or in June)

Material.—Leaves from growing shoots, some green, some wholly or partly white, Fehling's solution if available, iodine solution, test tubes or enamelled cups, spirit lamps, fresh stalks of grass, potatoes with long white shoots sprouted in a cellar or in a dark box ; a little common alcohol or methylated spirits.

In the afternoon, shortly before sunset, gather a few green leaves from rapidly growing plants which have been exposed to the light of the sun since morning. Nasturtium and Sweet Pea leaves

answer well for the following experiments, but you should try others also. Boil each leaf, or *part* of a leaf, at once, in water, for about a minute, and soak it in ordinary alcohol or in methylated spirits till the leaf-green is nearly or quite extracted. You may heat the alcohol to hasten the process, but if you do, be careful not to set it on fire. The leaf will gradually become nearly white.

Pour off the alcohol, wash with water, and cover the leaf with tincture (alcoholic solution) of iodine *slightly diluted with water*. If it turns blue or blue-black in color you must infer that it contains starch, and this is the result you will obtain if you perform the experiment at the proper time, and in the right way. Therefore, repeat the experiment if your results are not decisive.

Collect early in the morning some leaves from the same plants, and keep them in a dark box or closet; or better, cover the whole plant with a box till later in the day when you are ready for the next experiment. Then treat the leaves just as you did those which were gathered in the evening. You should find that they do not turn blue, as did the other leaves.

These leaves, like the others, no doubt contained plenty of starch in the evening before you gathered them. It must be, then, that the green leaves make starch in the daylight, and that the starch disappears from them in the darkness.

Find a leaf which is wholly or in part white, and test it for starch after boiling it in water. You will conclude that both leaf-green and light, as well as the heat required for the activity of the plant, are necessary for the making of starch in leaves, and presumably in the other green parts of plants.

Now we have found that starch disappears from the leaves in the night. We have shown also that starch is stored up in tubers, seeds and other organs. Indeed, starch appears to be the principal form in which carbohydrates are stored as food.

As the parts in which it is stored are devoid of leaf-green, the starch could not have been made in the organs in which it is stored. It must have been transferred from the leaves to the storage organs; but we found when we analyzed a potato that the starch was not soluble in the watery sap or juice. It is clear, then, that the starch made within the leaves must be changed into some form which will dissolve in cold water, for the solid starch could not pass through the plant from one part to another.

While starch is a carbohydrate insoluble in cold water, sugar is a carbohydrate which dissolves readily in cold water. Now we find that sugar is present in green plants where growth is going on. In the spring, when growth is about to begin in trees, the sap is sweet with sugar. Pull a growing stalk of grass in two; chew the tender white part

of the stem where growth is taking place. Test the sprouts of a potato with iodine solution and with Fehling's solution, if available. The sprouts may be cut into small pieces and boiled in water, and the liquid poured off and tested as in previous experiments. You may find sugar present. The material for making the sugar came out of the tuber. These with other facts which you can easily discover, point strongly to the conclusion that the starch formed in the leaves is transported from them to other parts of the plant in the form of sugar.

If the sugar is not used at once it may turn into starch again, as when starch made in the leaves of the potato plant is conveyed down the stalks in the form of sugar into the tubers, where it is reconverted into starch, which forms about 80 per cent. of the dry matter of a potato tuber.

If you leave some tubers in a dark box, little tubers will be formed on the white stems. If you test these little tubers for starch you will find a good proof that sugar can be changed into starch by plants.

EXERCISES

1. Write out in your own words an argument to prove that green leaves make starch in the day-time.
2. Prove that a plant, or at least some plants, can change starch into sugar.
3. Give proofs that sugar can be changed back into starch in a plant.

XXVIII. WHAT PLANTS MAKE STARCH OUT OF

(For a bright day late in May or in June)

Material.—Several wide-mouthed bottles, such as pickle-bottles or milk-bottles, a pail of water, saucers or glass nappies, tapers or candles, fresh leafy shoots from rapidly growing plants, a potted plant which has wilted for lack of water.

Water thoroughly the roots of a potted plant whose leaves have wilted for lack of water. Do not put any water on the leaves. Also get some shoots with wilted leaves in a vessel of water.

Hold a wide-mouthed bottle mouth down, and push a burning taper or a small candle up into it a little way. When the flame dies out, cover the mouth of the bottle with your hand. Turn it mouth up, and shake a little lime-water through the gas in the bottle. Evidently the candle contains carbon which in burning unites with the oxygen of the air in the bottle to form enough carbon dioxide to produce the observed effect on the lime-water.

Rinse the bottle and burn the taper in it again till the flame is extinguished. Put up into the bottle a leafy shoot from an actively growing plant. Push the burning candle up a short distance into the bottle beside the shoot, and, as soon as the flame dies out, promptly stand the bottle with its mouth down in a dish which contains enough

water to seal the mouth of the bottle and keep the gas inside from mixing with the air outside.

Prepare two other bottles in exactly the same manner. Set two of these bottles, with the dishes in which they stand, in or close to a sunny window, and set the other in a closet, or cover it with a box, to shut out the light.

Burn a taper in a fourth bottle till the flame dies out for lack of oxygen, and set this bottle mouth down in a dish of water, but do not put a leafy shoot into it. Set this bottle also in a sunny window. All these things should be done in the forenoon as early as convenient.

Before school closes in the afternoon, finish the experiments begun in the morning. Take one of the bottles set in the sunlight with a leafy shoot in it, dish and all, and lower the dish and bottle into a pail of water. Let the dish sink. Put your hand down into the pail of water and pull the leafy shoot down out of the bottle, taking care not to allow any air to enter the bottle. Cover the mouth of the bottle with your hand, raise it out of the water, turn its mouth up, and shake lime-water through it.

If you have performed the experiment successfully you will be forced to conclude that the carbon dioxide, which was produced in the bottle by burning the taper in it, must have been taken up or absorbed by something.

Place the bottle which had no plant in it with its mouth in the pail of water. Let the dish drop, turn the bottle mouth up with your hand upon its mouth, and shake lime-water up and down through it. The lime-water will become milky in appearance. You can now show whether it was the leafy shoot in the first bottle or the water which took up the carbon dioxide.

Take the plant out of the other bottle which was set in the light. In doing so, proceed as with the first, so as to admit no air. Raise it till its mouth is out of the pail and quickly try to burn the taper in it. Recollect that the taper would not burn in it when you set it in the sunlight. When the taper ceases to burn, shake lime-water through again. How do you explain the result of this experiment?

Turn next to the bottle set in darkness. Get the leafy shoot out of it as you did out of the others, and test the gas in the bottle with lime-water. The result will show whether the leaves in this bottle took up the carbon dioxide.

Let us now try to interpret all the facts brought out in these experiments. It seems that green leaves on a growing shoot take in during the daytime carbon dioxide from the air around them, but that this process ceases when the plant is in darkness, that is, in the night.

Think of this in connection with our previous

conclusion, that green leaves make starch in the day-time, but not at night. It seems that the leaves are absorbing carbon dioxide at the same time that they are making starch, and at night when they are not making starch they cease to absorb carbon dioxide. In other words, the demand for carbon dioxide ceases when the starch-making ceases.

This looks as though the carbon dioxide is used in making the starch, and this might well be, for carbon dioxide contains carbon, and starch consists of carbon, hydrogen and oxygen, the elements which compose water. The carbon dioxide might yield the carbon and oxygen necessary to produce starch, but it contains no hydrogen. This must be obtained from some other source.

Look at the plants whose roots we watered this morning, and the shoots whose leaves were withered. Probably by this time the limp, helpless-looking leaves have straightened up, and are now quite firm and vigorous in appearance. We know that there is water in the juice of leaves; but the water applied to the roots could certainly not make the leaves firm and plump again unless it had ascended the stem and footstalks and entered the blades of the leaves.

If leaves take in any water at all *from the air*, it cannot be much, for it does not keep the leaves from wilting; but if water be applied to the roots

it soon restores the wilted leaves. This shows why the rootlets require root-hairs. The root-hairs have such thin walls, and are so numerous, that they must absorb water faster than the main part of rootlets could.

We have just argued that leaves obtain the carbon for starch-making from the carbon dioxide taken in during the day-time, and now we see that leaves obtain much water which is carried up the stem to them from the roots. It is extremely likely, then, that green leaves make starch out of the carbon of carbon dioxide, chemically united with the hydrogen and oxygen of the water which was absorbed by the root-hairs, and ascended the stem to the leaves.


Recollect that when you heated starch in a closed tube, you obtained carbon and water from the starch. The leaves do not take in free carbon, but carbon dioxide, which consists of carbon and oxygen. They only need the carbon of this gas and not its oxygen in making starch, since enough oxygen to make starch can be obtained from water.

This explains why the taper would burn in the bottle in which the leafy shoot had been left for several daylight hours. The leaves, while they were making starch in the sunlight, were giving off as much oxygen as was contained in the carbon dioxide, from which they were using the carbon in starch-making. The leaves then must break up

the carbon dioxide and water, using the carbon, hydrogen and part of the oxygen in making starch, and setting the rest of the oxygen free. The oxygen, or part of it, must be exhaled from the leaves in the sunlight, else the taper would not have burned in the bottle afterwards.

Although starch in plants changes into sugar, the reverse also occurs. It is generally believed that sugar is formed before starch in the leaves, and is only converted into the latter when more is produced than can be used for food at once. Finally we may claim that cellulose, which is the most lasting of the three carbohydrates we have found in plants, is produced from the same materials as the other two. It is evident that plants make for themselves all the starch, sugar and cellulose they contain, for neither the soil nor the air contains any of these substances. When we consider what a large amount of wood one large tree contains, it astonishes us that this one plant should have been able to produce enough food in the form of starch or sugar to form such an immense weight of wood.

EXERCISES

1. Write out in your own words your reasons for believing that green leaves use carbon dioxide and water in making starch.
 2. Point out whether it is correct to say that a commercial starch factory *makes* starch. What is the fact?
 3. Show why trees and other plants need such an immense spread of leaf surface.
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XXIX. THE BREATHING OF PLANTS

Material.—Peas and sunflower seeds or other seeds which contain large seed-plantlets, wide-mouthed bottles, large corks, lime-water.

Soak a sufficient quantity of peas in water until their coats are easy to remove. As peas are seeds, each should contain a little plant. Confirm this by removing the seed-coat. How many leaves has the embryo of the pea? How many seed-leaves? Although this embryo is much like that of the bean you will notice some differences.

Put a little cotton wool drenched with water into a wide-mouthed bottle—a six-ounce (6 oz.) prescription bottle will answer well for this purpose—and cover the cotton with a layer of soaked peas about half an inch deep. Cover the layer of peas with wet cotton, and add another layer of peas. Cork the bottle so as to be nearly air-tight, and keep it in a warm place till the plantlets have advanced in germination so far that the roots extend a short distance outside the seed-coats, or until the flame of a match will be at once extinguished when held in the mouth of the bottle.

The young plants are now active, and should be breathing if they ever breathe. Plunge a burning match into a wide-mouthed bottle of air. Remove the cork from the bottle of peas, plunge the burning match into the gas above the germinating peas, and

immediately cork the bottle again. Then pour a little lime-water in upon the peas, place your hand tightly upon the mouth of the bottle and shake the lime-water up and down through the gas in the bottle. The lime-water should become quite milky in appearance.

To interpret these facts we can only say that the little pea plants must be generating carbon dioxide, and giving it off into the air. Other seeds besides peas—sunflower seeds for instance—should be used for this experiment, at the same time, in order to confirm the results obtained with the peas.

Blow your breath through lime-water till it turns milky. Carbon dioxide gas is being generated in your body and given off into the air. It is the end-product of the process, in yourself and animals generally, which you call breathing or respiration. The similar process in plants is called respiration.

It is plain that the little pea plants do not get all this carbon dioxide from the air in the bottle, else it would whiten lime-water before the peas are put in. Just as we need oxygen *from the air* to unite with the carbon in our bodies, so do plants need oxygen from the air to unite with the carbon present in the substances of which they are composed. In this way the compounds are broken up and energy imprisoned in them is set free for use

in growth and other life-processes. It is this oxidation of carbon in our bodies—as you have learned—that keeps our bodies warm—warmer than the surrounding air; but if plants breathe much more slowly than we do, and the heat produced passes off about as fast as it is generated, the bodies of plants should not be as warm as ours. Feel a plant and see.

EXERCISES

1. Push one or two growing leafy shoots into a wide-mouthed bottle, held mouth down, and set the bottle with its mouth in a dish containing enough water to prevent the outside air from entering the bottle. Cover the bottle with a box, or set it in a dark closet, and leave it in darkness for several hours. Then remove the shoot with the mouth of the bottle under water. Raise the bottle quickly, turn it mouth upward, and shake lime-water up and down through it. What has occurred?

2. Is there any reason for the belief that plants are unwholesome in a bedroom at night?

N.B.—The quantity of carbon dioxide given off by a few house-plants is so small compared with what is given off by the human occupant of the room that the danger from the plants is a negligible quantity.

3. Repeat the experiment in Exercise 1, with one variation—keep the bottle containing the leafy shoot in the light for several hours, instead of in darkness. Explain the difference in the results.

XXX. THE ABSORPTION AND TRANSPIRATION OF WATER BY PLANTS

Material.—Test tubes, cotton wool, potted plants in active growth.

Set a potted coleus, or some other plant with rather large leaves, in a warm room. Roll the blade of one of its leaves into a cylindrical form, and push it into a test tube without injuring the leaf-stalk or breaking it off from the stem of the plant. Then pack the mouth of the tube around the footstalk of the leaf with cotton wool, taking care not to crush the footstalk. The cotton will thus answer as a cork, and but little moisture can escape from the test tube. Let the tube incline so that a liquid would flow toward the bottom, and support it in that position so that its weight will not break or injure the leaf-stalk, cutting off communication between the blade of the leaf and the stem and root of the plant. In a short time a clear liquid will collect in drops on the inside of the test tube.

Supply the plant with water by keeping the soil fairly moist, and in a few days a considerable quantity of the liquid will have collected at the bottom of the tube. Remove the cotton stopper and the leaf from the tube, and test the liquid.

It is clear that the leaf must have been giving

off water from its blade. But why could you not see the water escaping from the leaf? It must escape in the invisible form of steam, just as perspiration from your body is invisible unless you exert yourself so actively that it collects in drops of sweat.

The giving off of water by the leaves of plants is called transpiration. It resembles the process of perspiration in yourselves; but if you try, you will find that the drops of perspiration are not nearly as pure water as the water transpired by plants.

The amount of water exhaled in one season from a field of corn or from a large forest must be very great. How is the supply kept up?

We have seen that plants need water for making starch, sugar and cellulose, that while they are living they contain free water—in their sap—and that they exhale water from their leaves quite rapidly in transpiration. It is plain that while the leaves are on the plants they must be regularly supplied with water, else they would soon become very dry. But this water is not absorbed by the leaves, for we find that they are constantly giving off water instead of taking it in. The bark on the stems and roots of plants is nearly water-proof, and keeps the plants from drying out.

The water used by plants, and that which passes off in transpiration, must be taken in through the

root-hairs which the rootlets bear in such vast numbers. As a striking evidence of this, allow a low plant, such as a primrose growing in a pot, to become so dry that the leaves are all wilted. Set the pot in a shallow vessel of water, and observe how quickly the water will reach the leaves from the roots buried in the soil.

To prove that the root-hairs really do spread from the rootlets into the soil in all directions, grow from the seed a few small plants in a pot of light-soil. Empty the soil out in a mass when dry, and carefully take the plants out of the soil. You will find many particles of soil clinging to the rootlets by means of the root-hairs, to which the grains adhere.

SECOND YEAR

AUTUMN LESSONS

I. THE CELL STRUCTURE OF PLANTS

Material.—Specimens of sunflower stalks and or other stems, fresh green leaves, germinating plants with root-hairs, flowers discharging pollen, a cheap magnifying glass, a sharp knife.

Cut with a sharp knife a thin section from the pith of a sunflower stalk and examine it under a magnifying glass. You will conclude from its appearance under the glass that it is made up of very minute parts, with thin walls or partitions separating them.

Indeed, if the piece of pith were sufficiently magnified it would look much like a honey-comb; and just as we give the name of cells to the little chambers which make a honey-comb, so we call those of the pith by the same name. The *cells* of the pith, however, are many times smaller.

Of course the hard woody part of the stem cannot be composed of such cells as those of the pith. If you scrape the wood with your knife-blade you will find that it will split lengthwise

into very fine threads or fibres. The fibres of the wood are also called cells, for they too are little chambers but comparatively long and very narrow, so that they resemble slender tubes closed at the end.

There are many forms of cells in plants. If you were to examine the skin of a leaf under a compound microscope, you could see the cells of which it is composed, and you would find that the pulp cells of the leaf resemble somewhat in form those of the pith of a sunflower. By scraping and splitting one of the veins of the leaf with your knife you can find the shape of the cells of which the veins are composed.

You can now see that a plant—even a great tree—is a mass of cells of various sizes and shapes, too small and too close together to be seen separately except with a microscope. You may picture out in your mind how a plant would look if your eyes were piercing and powerful enough to see through it, and at the same time see the many millions of cells of which it is built up.

You remember the root-hairs which you saw some time ago. Each of these hairs is a slender tube, closed at the tip, with a very thin wall extending out from a cell in the skin of the rootlet. A root-hair is only a part of a cell, for there is no wall separating it from the cell from which it sprang. Unless you use a microscope you

cannot see that part of the cell in the skin of the rootlet. It is very small, and the wall which separates it from the cells about it is too thin to be perceived by you; but the root-hair itself can be only seen with an ordinary magnifying glass.

A number of cells arranged together in one system are called a *tissue*; thus pith and the pulp of a leaf are one kind of tissue, the skin is another, and the veins of the leaf are composed of woody tissue. The substance of which the cell-walls of a plant are mainly formed is called *cellulose*. Cotton is nearly pure cellulose, the fibres of cotton being formed of long narrow dead cells. The wood of trees is largely of modified cellulose, the cell-walls having been thickened by the addition of a firmer, harder substance generally called *lignin*. Even the thin walls of the cells in the pulp of a leaf are composed of cellulose. So a plant-cell is a minute chamber with a wall of cellulose, which may be very thin and soft, or thickened and more or less rigid.

The little plants which we sprouted were made up of cells, but these cells must have been alive, else the plant could not have grown and could not be killed. Yes, every living plant-cell must have some living substance inside its cellulose wall. Of course the sap which we squeeze out of the cells is not alive. Nor is the leaf-green the living substance, for the uncolored as well as the

colored parts of a young plant are alive and grow. But microscopists find in every active cell a soft, glairy, colorless substance (resembling the "white" of a raw egg) which is not present in old dead cells.

This is the living substance of the cells, and is the only living substance in a plant. It is called *protoplasm*. You cannot expect to see it with the naked eye, or with a common magnifying glass, when you remember the minute size of each cell.

Are the cells of dry garden seeds dead? No; if they were the seeds could not germinate. The protoplasm in the cells of the seed-plantlet before germination must be dormant or in a resting state, yet capable of being stimulated into active life. That is what the warmth and the moisture help to do.

We can now understand how a plant grows. A plant is made up of minute cells, and, when it is growing, the number of these cells must be increasing. New cells are being formed from the older ones. This does not mean that the older ones are destroyed, but each of the cells in the growing part of the plant becomes two cells, and a cellulose wall formed across the middle separates them. Each of these two cells soon becomes as large as the parent cell which produced them and may divide in its turn.

Of course dead cells cannot divide to form new ones, nor do cells necessarily die as soon as they

cease dividing; but certainly all the dead cells now in a plant were once alive, for when they were formed from their parent cells they had living protoplasm in them.

Whenever any part of a plant begins to grow, there cell division is going on and new cells are being formed from the old ones. When a plant gets to be twice as large and heavy as it was, that means that it probably contains about twice as many cells as it did.

I should remind you that cells do not form a tissue unless they are joined together. Examine the pollen of a flower with a magnifying glass. The little grains of pollen as they are discharged from the anther are *separate* cells. The pollen of a flower, then, although made up of cells, is not a tissue.

When a grain of pollen germinates on the stigma of a flower, a *germ-cell* formed by the *internal* division of the pollen grain descends the pollen tube which penetrates an ovule (unfertilized seed). The ovule contains another germ-cell of a different sort, and here (in the ovule) the two germ-cells unite to form one new cell, called the *fertilized egg*. The union or fusion of the two germ-cells is called *fertilization*. Afterwards the egg-cell begins to divide, and cell-division continues till the egg has developed into the embryo. After resting for a time, the embryo, when placed under suitable con-

ditions, germinates, and develops into a flowering plant. So we see that every *flowering* plant begins its career as a single cell—a fertilized egg—which was formed by the fusion of two other cells.

II. THE COURSE OF THE SAP IN PLANTS

Material.—Sunflower leaves or other leaves with stout footstalks, stems of Indian corn and of the sunflower, carrots, potatoes, short leafy branches, some young plants growing in light soil, red ink or other red dye, black ink, tumblers and wide-mouthed bottles, shallow dishes.

Set a few fresh leaves with large footstalks, such as sunflower leaves, in a bottle or tumbler containing red ink slightly diluted with water. Cut a few pieces two or three inches in length from the stems of sunflower and of Indian corn, stand them in a shallow dish containing diluted red ink about half an inch deep, and take an occasional look to see the results.

If this experiment is started in the forenoon, in the afternoon you will be able to tell through which of the tissues of the stems and leaves the ink rises, and to calculate at what rate per hour it ascended the stems. Since red ink is a solution of dye in water, this experiment will show whether substances dissolved in soil water might ascend the stems dissolved in the water absorbed by the root-hairs.

Examine the leaves after several hours, to see whether the dye remains in the tissue through which it ascended, or whether it diffuses into the other tissues.

Stand some pieces of sunflower and corn stalks, with the top end down, in red ink, and note whether the ink will travel through the stem in the opposite direction, that is, toward the root.

Cut both ends off a short carrot and a potato, and set them in a shallow dish containing ink in the bottom. Use black ink for the carrot. Interpret the results.

Set short leafy branches of poplar or of some other tree in a wide-mouthed bottle or glass jar half full of a solution of red ink or of other red dye, to find whether the dye will pass with the water from the stem into the leaves. Peel the bark off the stem for the distance of one-half an inch a little above the level of the solution, and note whether the water and dye can ascend to the leaves through the part of the stem from which the bark was removed.

We have seen that if we supply water to the roots of a plant whose leaves are wilted, the water will soon ascend and fill the cell so completely that the leaves stiffen and straighten out again. To show that most of this water is probably absorbed by the root-hairs, grow from seed, in light soil, a few plants to the height of two or three inches.

Turn the soil out of the pot, and carefully take the plants out of it. You will find that much soil clings to the rootlets by means of the root-hairs which adhere closely to the particles of soil.

It is clear that the water which ascends the stems of plants must pass from the soil through the skin of the rootlets, or through the thin walls of the root-hairs. There are evidently no openings in the roots by which solid matter can be taken into the plant. Therefore only water and substances dissolved in it can pass through the thin walls of the cells and root-hairs.

Since the whole plant is composed of cells, the watery sap must ascend the stem and leaves by diffusion from cell to cell. Similarly, the starch made in the leaves when changed into sugar must pass through the stem from cell to cell, dissolved in the watery sap, to the other parts of the plant, to be used where needed, or to be stored up in tubers, bulbs, etc. We have seen that plants use water in the *manufacture* of starch—the starch being composed of carbon and the elements of water chemically united. Here we find another use of the water in plants, for the transference of sugar and other substances from one part of the plant to another could not take place unless these substances were dissolved in the water of the sap.

III. FERNS AND OTHER GREEN SEEDLESS PLANTS

Material.—Fresh specimens of ferns and other green seedless plants, such as horsetails, club-mosses, mosses, and, if obtainable, pond-scums in water.

The green spreading *fronds* of ferns are evidently leaves, but where are the stems which bear these leaves? In our ferns the stems must be concealed in the earth below the fronds. These stems are root-like in appearance, but since they bear the leaves of the ferns they must be true stems.

The footstalks of the compound fronds might be mistaken for stems, but you will notice that the divisions of the fronds are not set on the footstalk like leaves on a stem, so we must regard the whole frond, no matter how much it is divided, including the stalk which supports it, as a single leaf. The roots will be found extending from the stem into the surrounding soil.

Upon the backs of some of the fronds may be seen small dots (*sori*) made up of little spherical bodies which become plainly visible if you use an ordinary magnifying glass. A sorus would thus suggest a cluster of minute berries, partially concealed, in most ferns, by a thin membranous covering. The minute berry-like bodies are called spore cases because each one is filled with still more minute grains called spores. So a sorus is a collection of spore-cases.

Rub a dry sorus hard enough to burst the spore-cases, and you will obtain a powder the grains of which are so fine that you cannot make out their form without a microscope of considerable magnifying power. Every particle of this dust-like powder is a *spore*.

If you collect some mature spores which have been freely discharged from the spore-cases of a fern and scatter them on suitable soil where the conditions will be similar to those where ferns grow naturally, you may have the pleasure of seeing them grow into tiny green bodies which produce eggs and male cells from whose union young fern plants will develop. In greenhouses, ferns are often grown thus from the spores. Although a spore gives rise to a new plant, it is not a seed and contains no minute embryo as a seed does. Like a pollen grain, it is a single cell capable of growth.

There are other families of green flowerless plants besides ferns. The principal of these are the horse-tails, club-mosses, often called trailing pine, true mosses and algae.

The horse-tails are very familiar objects, especially in the early spring. Then these plants send up slender jointed stems, whose leaves are merely whorls of teeth surrounding every joint like a sheath. At the top of each stem is a spike or club-shaped body made up of tiny shield-shaped leaves in close contact. On the inner side of each scale are several spore-cases containing many spores. After the spores are shed the stems may give rise

to whorls of green branches, or other stems spring up and become richly branched. As in the fern, the spores grow into minute structures which produce eggs and male cells. These must unite to form a new horse-tail. The life-history of the club-mosses is similar to that of the ferns, but they differ from them in form and habit. Creeping over the ground beneath the trees of our woodlands, their slender, flexible, evergreen stems covered with short leaves are very decorative. Their spore-cases are crescent-shaped and occur singly at the bases of leaves—either the ordinary leaves or special leaves differing in form from the others and arranged in a terminal spike.

The mosses are a much more primitive group of plants, with short leafy stems. The spores are produced in solitary spore-cases, usually borne on slender leafless stalks.

Sea-weeds or marine algae grow in the sea—chiefly along the shores, but often at some distance out from land. *Fresh-water algae* are common in ponds and slow streams. They often form soft, green, stringy masses, floating in the water. Such fresh-water forms are called *pond-scums*.

EXERCISES

1. Make a collection of the most beautiful ferns, horse-tails, club-mosses and mosses you can find in your neighborhood. The plants may be dried between sheets of porous paper. Old newspapers answer the purpose well.
2. Find some pond-scums, take them to the school, and keep them in water for a while that all may observe them.

IV. MUSHROOMS

Material.—Specimens from the woods and fields of various forms of mushrooms, including gill-bearing and pore-bearing species.

Some forms of mushrooms are known to children as toadstools. Some closely related plants are called puffballs. The common mushrooms we see growing on the ground, mostly in soil rich in humus (decaying vegetable matter), with their circular caps and erect stalks, resemble little umbrellas in form. If you examine the spreading caps, you will find the under side in some species divided into thin blade-like parts, with narrow spaces between the divisions. These divisions, which radiate from the centre, are called *gills*; and mushrooms which have them are called *gill-bearing* mushrooms.

Cut the stalk off a mature gill-bearing mushroom, place the cap, gills downward, on a piece of white paper, and cover it with a glass jar or other vessel, to prevent air currents. Before long, lines of very fine powder may be seen on the paper just below the slits between the gills. This powder is made up of the spores from which mushrooms grow, each spore being a single cell.

We see from this that the cap of the mushroom is a spore-bearing organ. The vegetative part of the mushroom is rarely observed; it may be found

by digging into the earth about the base of the stalk. It is made up of threads which spread through the earth, drawing food from decaying vegetable matter in the soil.

Edible mushrooms are grown by the cultivators of mushrooms from the underground vegetative part, which is sold under the name of mushroom *spawn*. The mushroom lives for a time in the form of spawn, then the spawn sends up a stalk with a cap on it for producing spores.

In some mushrooms the lower side of the cap is perforated with many small openings called *tubes* or *pores*, which answer the same purpose as the gills in other mushrooms.

The *pore-bearing* mushrooms are of different forms. Some species of them are common on trees. They are often quite tough and sometimes hard, and resemble little shelves or brackets fastened to the tree. These are called bracket or shelf mushrooms.

The bracket, however, is only the spore-bearing part of the mushroom. Most of the mushroom—the vegetative part—is concealed within the tree upon which it may have been feeding for a long time. Upon splitting a log which has shelf mushrooms on it you can find the vegetative part of the mushrooms within, and observe the effect on the tree. These mushrooms destroy the wood of living trees and may finally kill them. Bracket

mushrooms grow from spores which fall upon a wound in the tree, and, germinating there, grow into the tree.

Puffballs are neither gill-bearing nor pore-bearing mushrooms. The black powder which issues from the ripe ball is made up of a vast number of spores, each of which is capable of producing a new puffball.

Some mushrooms are good for food, but there are so many poisonous ones that it is not at all safe for inexperienced people to eat those of their own selection.

Mushrooms are often white, but many kinds are brightly colored. They contain no leaf-green, and so we know that they must obtain their food from material prepared by other plants. Many of them live on the decaying bodies of plants buried in the soil; others, such as the bracket mushrooms of trees, obtain their nourishment from living plants.

EXERCISES

1. Make a collection of mushrooms from the fields and woods, noting at the same time where they flourish best.
2. Draw two or three mushrooms of different forms.
3. Try to grow some mushrooms from spawn or from spores, or from both.

V. MOULDS

Material.—Small pieces of bread, cheese, boiled potato, lemon, fresh leaves, glass jars (self-sealers), plates, tumblers, flower-pots or bowls.

Place a boiled potato, a piece of bread saturated with water, a dry piece of bread, a thick slice of lemon, some damp leaves, a piece of cheese, respectively, on plates and invert a tumbler over each. Prepare duplicates of some of these, and place a flower-pot or bowl over each tumbler in order to exclude the light. Set the whole in a warm place.

Put a boiled potato and a piece of bread separately in glass jars with air-tight covers. Place the jars open, and their covers—rubber band and all—in a pan of cold water, and bring the water to the boiling point. Allow the water to boil for a while, then quickly turn the jars with mouth obliquely downward, allow the water to drain out, and promptly put the covers on the jars before turning them mouth upward. Screw the cover down, and keep the jars in a warm place. Cover one of the jars to shut out the light.

Look from time to time to see whether any new growths appear on any of the substances under the tumblers or in the jars. Note whether the new growths are all alike, or whether they differ in form, in color, or in other ways.

After a time you will see on some of the materials, perhaps on the bread, a beautiful white growth, apparently composed of fine fibres or threads. Soon very small round black bodies, resembling black pin-heads, will appear upon the white threads. These will probably increase greatly in number, until the whole mass is speckled with black. This white growth which bears the black specks is a *mould*, and the little black balls are full of fine powder.

You will probably find that no moulds have developed on the bread in the sealed jars, but if you sift upon it a little of the powder from the moulds under the tumblers, and cover the jars loosely, you should soon see an extensive growth of moulds. Try whether the moulds grow better when the jar is sealed tightly, or when the cover is left slightly loose.

Every particle of the fine powder from which moulds grow is a spore. A mould spore is a single cell which is capable of developing into a mould plant.

The species of moulds just referred to is one of the black moulds. You will probably find other moulds in which the spores are bluish or greenish in color. These belong to the blue moulds.

Since moulds do not contain leaf-green they cannot use carbon dioxide and water to make the starch and other carbohydrates which are used in

building up living matter and cell-walls. This means that moulds cannot make their food out of inorganic matter as green plants can. Like animals, they must use food which has been already prepared by green plants.

The moulds which you have just examined use the starches and other substances in the bread on which they grow. If you examine bread on which they have been living for some time, you will see that threads of the mould have spread through the bread and are absorbing food, breaking down the bread and making it decay.

EXERCISES

1. Show whether moulds are flowering or flowerless plants.
2. Find whether moulds grow better in light or in darkness—in a cold room or in a warm room.
3. Try whether moulds will grow on dry substances.
4. Explain how the moulds came to grow on the substances under the tumblers, although you had sowed no mould spores there.
5. How can mould spores be killed, and their growth prevented?
6. Heat a piece of boiled potato in a jar of boiling water, pour off the water, sprinkle dust from the floor on the potato, and cover the jar. Set the jar in a warm place, and account for the growth of moulds on it, if any appear.
7. Find whether mould spores are floating about in the air.
8. Remove the cover from a can of fruit and replace it at once. After a few days, compare it with a jar which had been unsealed.

VI. YEASTS

Material.—A fresh cake of yeast, a cup of molasses, a little wheat flour, granulated sugar, lime-water, wide-mouthed bottles of different sizes, test tubes or homeopathic vials, a soda-water bottle, wooden test-sticks, a spirit lamp.

You have learned that fungi, like animals, must depend upon food prepared by green plants. When digesting such foods, they often produce waste substances which are sometimes used by man. The most familiar of these is alcohol. Both the ancient Egyptians and the children of Israel knew how to make wine from the sugary juices of grapes and how to prepare "leavened bread." They did not, however, know that both processes result from the growth of plants which you will now study.

Stir up half of a fresh yeast cake in a tumbler of water. The other half of the cake, if needed, may be used in the following experiments. Mix in a large bottle half a cup of molasses with about seven or eight times its volume of water.

Make a small ball of dough—not too soft—by mixing a little wheat flour with water into which you have stirred yeast. Make two other balls of dough, using water without yeast in one, and some of the molasses solution with yeast in the other. Drop the three lumps of dough into three wide-mouthed bottles. The dough should occupy about one-third of each bottle.

Cork the bottles loosely and set them in a warm place (near a stove or a radiator) for several hours, until the dough expands in one or more of them to double its original volume. Try whether a match will burn in the mouth of each bottle. Test for carbon dioxide by tipping the open mouth of each bottle over the mouth of another bottle containing a little lime-water, and then shaking the lime-water through the bottle. Close the bottle tightly with the hand while shaking the lime-water through it. Observe the smell given off by the risen dough.

Fill several test tubes or vials one-third full of molasses solution, add a few drops of the mixture of yeast and water to each, cork the tubes or vials, and set the whole in a warm place. Watch the action which soon sets in, and after some hours go through the motion of emptying the gas above the solution into a two-ounce bottle with one-third of an inch of lime-water in the bottom. Close the bottle and shake the lime-water through it.

If you do not get a decided result at first, repeat the experiment, using another tube or vial. Note the smell given off from the solutions containing the yeast.

Fill a pint or a half-pint bottle half full of a fairly sweet solution of granulated sugar (cane sugar), add a tablespoonful or two of the mixture of yeast and water to each. Cork the bottles, not

quite air-tight; set them in a warm place, and note and account for the results. The *beery* smell from one of the solutions is due to the presence of alcohol, formed by the action of the yeast. Try whether this beery smell is given off from the test tubes or vials containing molasses solution and yeast.

Put some of the frothy scum which collects on the molasses solution in which the yeast is working into another bottle containing a molasses solution. Keep the solution warm and explain the result.

Fill a soda-water bottle two-thirds full of molasses solution, add yeast, cork *tightly*, and leave the bottle in a warm place till the cork disappears. Explain this circumstance.

Boil a molasses solution containing yeast, and observe whether the yeast acts as before. Explain the result.

When yeast is studied under a microscope of considerable magnifying power, we find that it is made up of small cells, usually rounded in form, which multiply rapidly under favorable conditions by new cells budding off from the older ones. The new cells readily separate from the parent cells, and grow to be as large as they.

A yeast cake is just a mass of yeast cells stuck together. Each yeast cell is a minute plant.

Since yeasts contain no leaf-green, and live, like mushrooms and moulds, on material prepared by

other plants, they are included with the bacteria, the moulds and mushrooms in the great group of *fungi*. A yeast is a budding fungus.

The action of yeast in producing alcohol and carbon dioxide from sugar is called alcoholic or vinous fermentation.

EXERCISES

1. Try whether yeast will live and multiply in a mixture of starch (raw or boiled) and water.
2. Find whether yeast will thrive in a cold place.
3. (a) What two substances are produced by yeast in dough, and in a molasses solution? (b) From what do these two substances seem to be produced?
4. What caused the cavities in the dough which was raised by the yeast? How can these cavities be made permanent?
5. What two substances are expelled by the heat when dough which has been raised by yeast is baked in bread-making?
6. Why is yeast used in making bread?

VII. BACTERIA AND THEIR WAYS

(Look over this article to see what material is required for the experiments)

You have learned that mushrooms and moulds feed upon the bodies of other plants, and often cause their death and hasten their decay; but it has been found by means of the microscope that the putrefaction and decay of organic matter is largely due to minute, one-celled plants called

bacteria (singular *bacterium*). These minute plants are so small that only a high-power microscope will magnify them sufficiently to render them visible to us; indeed most of them must be magnified about 1,000 times before we can see the little cells, each of which is a single bacterium. Although we cannot see the individual bacteria without a microscope, we can observe them in masses, called *colonies*, with the naked eye.

Press a little hay into the bottom of a bottle, fill the bottle up with water, set it aside in a warm place for a few days. A gelatinous scum will form on the surface of the water. This scum is a mass of bacteria. If you were to place a speck of this scum in a drop of water, under a powerful microscope, you might see great numbers of bacteria lying or swimming about in the drop.

Cut a damp cooked potato into slices about half an inch thick, and then cut the slices into cylinders of such diameter that they can be dropped into a small wide-mouthed bottle. Put one or two cylinders into each of five bottles, and plug the mouth of each bottle rather tightly with a stopper made of cotton wool. This will prevent the entrance of bacteria, while not excluding the air.

Procure an enamelled pail or a deep basin with a cover. Invert in the bottom of it a low dish with a flat bottom which has been perforated with small holes. Pour in some water, and set *four* of the



(a)



(b)



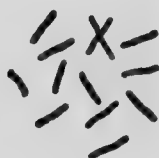
(c)



(d)



(e)



(f)

FORMS AND STATES OF BACTERIA

(All greatly magnified)

(a) ROD-SHAPED BACTERIA (BACILLI). (b) SPHERICAL BACTERIA (COCCI). (c) SPIRAL BACTERIA (SPIRILLA). (d) BACTERIA MULTIPLYING BY FISSION. (e) BACTERIA FORMING SPORES (INSIDE). (f) THE BACTERIA OF CONSUMPTION (BACILLUS TUBERCULOSIS).

bottles on the perforated bottom of the dish, cover the pail or basin, set it on a hot stove, and boil the water for thirty minutes. The heat of the steam should kill most of the bacteria that may have been on the potatoes or elsewhere in the vessel. The process of killing the bacteria by heat is called *sterilization*, and the apparatus we used in this instance may be called a steam *sterilizer*.

In order to find whether all the bacteria are killed, leave the bottles in a warm place for twenty-four hours, and steam three of them again for thirty minutes. Wait another day and steam two of them for the third time. Label all the bottles to show how often each was steamed. Put them back into the vessel and keep them in a warm, dark place near a stove or a radiator.

Look at the bottles from time to time; but of course do not remove the cotton stoppers. You will probably soon see moulds growing on the potato in one of the bottles. Quite likely there will be bacteria growing there as well, but these you cannot see. It is probable, too, that signs of decay will appear on one or two of the other pieces of potato on which no moulds develop. A slimy growth may appear on the surface, which may gradually spread. This is due to the growth of bacteria on the potato.

Hot steam will kill most bacteria in their

ordinary condition, in a short time, but it has been found that many bacteria form *spores* which will withstand the heat of boiling water for a long time. If bacterial decay takes place in any of the bottles which were steamed once, it is due to the development of spores which were not killed by the heat.

Note whether either moulds or bacteria grow on the potatoes which were steamed two or three times. If not, account for the fact.

You may next inoculate a slice of sterilized potato in a sterilized bottle with bacteria from the hay infusion. Take a long needle or a hat-pin and sterilize it by passing it several times through the flame of a spirit lamp. *As soon as the needle is cool*, dip it into the film on the surface of the hay infusion. Hold the sterilized bottle containing the potato nearly horizontal. Remove the stopper, draw the point of the needle once across the surface of the potato, and replace the stopper at once. Expose another slice to the air, by removing the stopper from the bottle for five minutes. Observe these two cases carefully, note and explain the results.

Sterilize some water by boiling it in an enamelled cup. As soon as the water is cool, with a sterilized needle take a small drop from the surface of the hay infusion and stir it in the water. Sterilize the needle again; dip it into the water and touch the

sterilized potato at a few points with the point of the needle. Plug the bottle immediately with sterilized cotton wool and set it in a warm place, not in direct sunlight. Watch to see what the result will be. If you used water enough the bacterial growth at each spot probably came from a single bacterium. The infected spot, although quite small, will contain a whole colony of bacteria, numbering many thousands, for bacteria in the active state multiply with wonderful rapidity. Each bacterium being a single cell divides in two to form two bacteria. This division, under favorable conditions, takes place in about half an hour, and if kept up for a day at this rate one bacterium would increase to many millions. Make a calculation of the exact number.

The colonies of bacteria sometimes differ in color. This means probably that they belong to different species. Some species of bacteria may be distinguished by the color, shape and appearance of their colonies. The individual bacteria of different species differ in size and form, but of course this cannot be seen without a microscope.

While some bacteria aid in the decay of dead animals and plants, others attack living beings and thus cause many diseases. Diphtheria, tuberculosis, typhoid fever, and many other diseases are due to the growth of bacteria in the body.

Some bacteria like those of pus and of erysipelas

affect only limited portions of the body. Others may themselves become widely distributed. Sometimes poisonous substances formed by the bacteria, as in diphtheria, may spread through the body. Scientific men have found and are still trying to find out ways of killing the bacteria, or of counteracting their poisons, without killing the persons suffering from the diseases caused by them.

Bacteria are often called *germs* or *microbes*. Germ diseases can be transferred from one person to another. The disease germs may pass from a diseased person to another through the air or by contact.

Disease-producing bacteria are frequently found in water and in milk. In case of suspicion, it is wise to sterilize the water before drinking by boiling it. The milk should be heated to 155° Fahr. for twenty minutes and then cooled. This process, called *pasteurizing*, will kill the disease-producing bacteria in the milk.

If we keep our bodies clean and pure and our health vigorous, we are much less liable to be attacked by the bacteria of disease. Cleanly habits, enough but not too much good food, daily exercise in the open air, and well-lighted and ventilated rooms in which to work and sleep, all contribute to protect us from the attacks of these dangerous germs, and to fit the body to resist them if they do find a lodgment.

But we must not forget that many bacteria are useful or at least harmless. The bacteria of decay are useful in removing the dead bodies of plants and animals. The soil contains great numbers of bacteria which are of service in preparing food for the higher plants. Some bacteria cause fermentations, such as acetic fermentation, by which beer, wine or cider is converted into vinegar, and lactic fermentation, by which the sugar of milk is converted into lactic acid. Bacteria help to ripen cheese and impart to it an agreeable flavor, and in many other ways they play a useful part in the economy of nature.

EXERCISES

1. Make a collection of specimens from the home and from the fields and woods illustrating the work of bacteria.
2. After a bottle containing a solution of molasses in water has undergone alcoholic fermentation, set it aside uncorked till the solution smells like vinegar (acetic acid solution). Test with litmus paper. Account for the change, and point out what became of the alcohol.

WINTER LESSONS

VIII. THE DOMESTIC ANIMALS OF THE HOME AND FARM

ALL our domesticated animals once lived the independent life of wild creatures, maintaining the struggle for existence alone by their own powers of self-preservation.

The dog and the cat, were domesticated thousands of years ago, probably before there was any written history, and while man was still a savage. The dog is believed to have at first resembled a wolf or jackal, preying perhaps in packs upon the less aggressive wild animals of the forest and the open plain. He has been greatly changed during his long association with man, and has developed traits which seem to be quite human, such as his evident pleasure at being praised. Indeed, in his warm response to the affection of his master, and his faithfulness to him even in adversity, he displays qualities only too rare among men. In earlier ages the dog was no doubt of great service to man in safeguarding him against his enemies, and assisting him in the chase.

The cat retains more of the original savage characteristics of her wild ancestors than does the

dog. The cat has done considerable service in ridding man of meaner enemies, such as mice and rats.

In these days, however, dogs and cats are in general not so necessary to us. Indeed, in many communities cats are far too numerous. They destroy large numbers of song birds, and it is probable that they often carry the germs of infectious diseases in their frequent visits from house to house.

Our domestic cows and oxen are descended from the wild cattle which once roamed over the plains of the Old World, as did the buffaloes not long ago over our western plains. During many generations they have contributed largely, in food and clothing, to supply the needs of the tribes and nations who domesticated or adopted them. The ox has done an immense amount of work for man—hauling the cart, dragging the plough, and threshing out the grain.

Many breeds of cattle have been developed in different parts of the world. Some breeds have been specially adapted for producing milk; others have been bred chiefly for beef.

The sheep was originally a mountain animal, active and sure-footed, able to leap from cliff to cliff and scale the mountain peaks. Wild sheep are still found in mountainous regions in both hemispheres. Sheep formed large part of the

wealth of the pastoral tribes of Asia ages ago. In cold-temperate countries their wool is indispensable for clothing, and their flesh forms a large part of our animal food.

The horse, the noblest of our domestic animals, was tamed in very early times by savage peoples. He has long been employed, both in peace and war, as a source of speed and of power.

The ancestors of the domesticated horse wandered over the plains of the Eastern Continent, but it is quite doubtful whether the original wild horse still exists. It is generally believed that the modern wild horses of Asia are descended from domestic animals which have escaped from the control of man.

There were no horses either wild or tame in America at the time of its discovery by Columbus. Geologists tell us, however, that there were horses in America long ages ago, but that they all died out. The American horses of the present day are descended from those brought across the Atlantic since the year 1492.

Breeding for speed has given us the race-horse, while breeding for power has developed the draught-horse at the other extreme. Horses are now very commonly used for general farm work, taking the place, as a beast of burden, formerly held by the ox.

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HAPPY ON THE RANGE.

Reproduced by permission of U. S. R. Conservation Department

ferocious beast—a wild boar—in the forests and jungles of the Old World. As a domestic animal, all that is required of the pig is to grow fast and fat, on such food as its owner permits it to have. It has accordingly degenerated in self-reliance and in intelligence.

The species from which our domestic fowls are derived can still be found in the wild state. The domestic hen came from a species of wild fowl which still inhabits Northern India and other parts of Eastern Asia. Our tame ducks are descended from the wild duck, and the domestic goose from one or more species of the migratory wild geese of the Eastern Continent. The turkey is a native of America and is still found wild in the southern part of the United States and further south. The domestic turkey is probably derived mainly from the Mexican variety of the wild turkey. This fowl was introduced into Europe soon after the discovery of Mexico.

The Care of Domestic Animals. Since man deprived the domestic animals of their wild freedom, they have largely lost their powers of self-defence and their habits of self-reliance. They have become dependent on man for protection, food and shelter, and frequently suffer from their owner's neglect to provide for them. This is not only cruel on the part of their owner, but is always a cause of financial loss to him. Animals which are well

fed and cared for will always give their master a more satisfactory return.

All the domestic animals—like human beings—require nourishing food containing a sufficient amount of carbohydrates and proteins (not forgetting enough common salt to supply the natural craving of the animals), pure air to breathe, pure water to drink, clean bodies, exercise, and a temperature at which they can be comfortable. Our northern winters are so cold that they all need more or less shelter from its severities. The buildings provided for their shelter in winter should be clean, well-ventilated, dry, free from draughts, and well lighted from windows.

It is very important that the animals should not be kept too warm. Stables for cattle and horses should be kept in winter at a temperature ranging from about 45° to 55° Fahr.

Cattle as well as horses should be groomed regularly with brush or comb, and their stables should be provided with straw or other litter for bedding. Sheep demand greater freedom than cattle, and their warmer coats protect them better from severe cold. They may be allowed to run freely in and out of their sheds, except at night.

Poultry-houses should be of light construction. The same conditions as to draughts, ventilation, light, cleanliness and dryness apply to them as to the stables for cattle. In cold weather poultry,

like other animals, require a warmer place in which to sleep than they need for exercise and free movement, but the temperature should never be above the point of comfort.

Hens are fed mostly on grain—wheat, corn, and oats—but also require some softer food, and also green food. In *fattening* fowls, food for the morning meal may be prepared by boiling together clean vegetables of nearly any kind, and stirring in corn meal, bran, ground oats and ground meat, with a little salt—till the whole mass is quite firm and dry. Fresh clover makes good green food. Bones and meat shaved in a bone-cutter make a valuable addition to the food of laying hens, but must not be fed too often or in too large quantity. An ounce to each hen is enough at a time. Poultry require pure fresh water (*warm* in winter) and gravel or sharp grit, as regularly as they need food.

The same principles as to care and food apply in the management of all kinds of fowls; but in carrying out these principles we must keep in mind the natural characteristics and habits of the different species.

Poultry-keeping is very profitable if well managed. The necessary knowledge and skill can only be gained by experience, but the reading of good books and newspaper articles on the subject will shorten the time needed in acquiring experience, and lessen the loss due to mistakes.

We must not forget to mention our domesticated insect, the honey bee. These busy little creatures do well in favorable localities, when under the care of someone who will take the trouble to study their habits and their needs.

IX. THE COMPOSITION AND CARE OF MILK

Material—A pint or two of milk, a sample of milk sugar, a little extract of rennet, hydrochloric acid, vinegar, litmus paper, a muslin strainer, tumblers, bottles, spoons, enamelled cups, a spirit lamp.

You do not remember it, but during the earliest weeks or months of your life your food consisted entirely, or almost entirely, of milk. Indeed the young of all mammals—including man as well as those animals next below human beings in the scale of existence—are fed on milk alone for some time after birth.

It is evident, then, that milk must be a nourishing food, and that it must contain all the substances necessary for building up bone, muscle, nerves, brain, and the other tissues of the animal body. Let us try to find by experiment some of the substances of which milk is made up.

Set some fresh milk aside in a narrow bottle for a few hours until it separates into two layers. The layer which forms at the top is called *cream*

Compare, by actual measurements, the depth of the cream with that of the milk below it. Skim off the cream. The milk remaining after the removal of the cream is called *skim milk*. Try which feels more oily—the skim milk or the cream—and which will give the better oil spot on paper.

We see that the greater part of the oil in milk has risen toward the surface and is now in the cream. The oil in the milk is not dissolved there, but exists as very small solid globules which cannot be seen without a microscope. The oil of milk is called *butter fat*.

You know that oils are lighter than water, and you can easily show by shaking any oil up with water that it will not dissolve in the water, but will soon rise to the top when the water becomes still. This explains why the globules of fat rise to the top in the milk. They are not dissolved like the other solids in the milk, and being lighter than water they tend to rise. The cream, however, is not pure fat. It is only milk which is very much richer in fat than the skim milk, and it contains a less amount of the other constituents of the milk.

When we agitate the cream in a churn the constant motion causes the globules of fat to stick together and form grains of butter. The butter is taken out of the churn when the grains

get to be about as large as wheat grains. The part of the cream which remains after the butter is taken out is called buttermilk. One hundred pounds of good average milk should yield about 20 lbs. of cream, and 20 lbs. of cream should yield about $4\frac{1}{2}$ lbs. of butter.

The butter itself is not pure fat, but contains in small proportion all the other substances found in milk. The buttermilk should contain very little fat, but all the other constituents of the original milk are represented in it. Buttermilk is a nourishing and very digestible food.

Heat a little milk in a cup or a test tube till a skin forms over the surface. You can recall the fact that the protein dissolved in potato juice was solidified by heating the juice. Similarly the protein in milk is solidified (coagulated) by heat. The tough skin formed on the milk by heating it is not pure protein, however, for some fat and other solids of the milk are entangled with it.

Warm a tumbler of ripened milk till its temperature is about that of the human body, and add enough extract of rennet to curdle it. The substance which was solidified (coagulated) by the rennet is called *casein*. Casein is the principal protein in milk. The white curd or clot, however, is not composed of casein alone, for when the casein coagulated, the fat and another protein, albumin, were caught or entangled in the clot,

as well as a portion of the other substances in milk.

Squeeze the liquid out of the clotted milk through a thin cloth into a bowl or cup. This liquid is called *whey*. The curd in the cloth, if properly pressed and cured, would be *cheese*.

Taste the whey and evaporate some of it very slowly to dryness. The whey has a very watery appearance. Catch in a cold tumbler some of the vapor which escapes during the evaporation, and identify it by touch and taste. You will find that whey is mostly water, and since the water in the whey was first in the milk, milk must consist chiefly of water. Indeed seven-eighths of milk by weight is water.

But what makes new milk sweet? You may call the sweet substance *milk-sugar*, and since most of the sugar remains in the whey, milk-sugar is obtained by the evaporation of whey. Find whether milk-sugar is more or less sweet than ordinary sugar.

Set some fresh milk aside in a warm place till it curdles; then taste it, and test it with litmus paper. The acid which formed in the milk is called *lactic acid*. It is formed from the milk-sugar through the action of a kind of bacterium. Try whether hydrochloric acid and vinegar (dilute acetic acid) will coagulate the casein as lactic acid does.

Heat a piece of curd in a metal dish or a spoon

until all the material which will evaporate or burn has disappeared. The remainder is mostly the ash or mineral matter of the milk. You may not be able to burn out all the charcoal, and therefore the ash will look black. The ash of milk is made up of various salts, one of which is phosphate of lime (calcium phosphate), which is the principal constituent of the bones of animals.

A great many kinds of bacteria are liable to get into milk and multiply rapidly there. Some of these produce changes in the milk which spoil it for drinking and for the making of butter and cheese. Some disease-producing bacteria multiply rapidly in milk if they gain admission, and render it very dangerous to drink.

It is possible, however, to secure a regular supply of good clean milk. The cows must be free from disease. They must be kept in a healthy condition by good food and intelligent care. The utmost cleanliness is indispensable. Their stables should be well ventilated and well lighted. They should have enough pure water to drink. They should be brushed regularly, but not at milking-time, as the dust contains many forms of bacteria. Less dust, and therefore fewer bacteria, will fall into the milk if the udder and adjoining parts are wiped with a damp cloth just before the cow is milked.

The room and all the vessels in which the milk

is kept must be scrupulously clean. Wherever there is dust, dirt or decay, there are bacteria. All the vessels used in holding or transferring the milk should be thoroughly washed with warm water and soap after being used and then scalded with hot water before they are dried. The same thorough cleanliness must be observed throughout the processes of cheese-making and butter-making.

Everyone who sells or uses milk and its products should keep fully informed on the methods by which they may reach the table in the best condition. The details of these methods are given in books and bulletins on dairying.

EXERCISE

Heat a few crumbs of dry cheese in a test tube while holding, by means of a wire, in the mouth of the tube, a piece of damp red litmus paper. Account for the change of color. (See pp. 73 and 74.)

X. A LESSON ON LIMESTONE

Material.—Spirit lamps, dilute hydrochloric (muriatic) acid, lime-water, a little unslacked lime, red litmus paper, test tubes, wide-mouthed bottles, knives or pointed pieces of steel, fine iron wire, wooden test sticks, small bowls, a cheap balance.

Each member of the class should be supplied with a few small fragments of limestone, and one larger piece. If ordinary limestone cannot be obtained in the locality, waste marble will answer, since marble is a variety of limestone.

Try whether limestone is hard enough to scratch glass or soft enough to be easily scratched with a knife. Notice its streak, that is, the color of its powder. That is found by simply scratching it

with something which has a hard point. A little powder is left lying in the groove thus made.

Put a drop of hydrochloric acid on the stone. If it is really limestone, bubbles of gas will arise from it wherever the acid touches it. These properties will enable you to distinguish limestone of any variety from other minerals.

Procure a piece of fine iron or steel wire (florist's wire), and bend one end of it into the form of a catch to hold a *very small thin* fragment of limestone. Hold this bit of limestone, by means of the wire, in the hottest part of the flame of a spirit lamp, and keep it glowing there for about five minutes, or till the thinnest part of it looks white and lustreless when cool. Observe that neither the limestone, nor the white substance produced from it by the heat, will burn. When it becomes cool, drop the fragment from the wire upon a piece of red litmus paper, and wet it and the paper with a drop of water. You will soon notice a decided change of color in the paper.

Try whether a piece of limestone which has not been heated will act on the litmus in this manner; also try a bit of lime.

You will find that the white powdery substance produced by heating the limestone resembles lime in its physical properties, and acts on damp red litmus paper as lime does, from which we may conclude with some certainty that the dull white

substance is lime. So by heating a piece of limestone we have obtained a little *lime*.

Put a teaspoonful of small fragments of limestone into a test tube or a small bottle. Add a little water to the limestone and observe whether any visible effect is produced. Pour the water off, and add enough dilute hydrochloric acid to cause an active bubbling. Hold the test tube or bottle so that the gas as it issues may fall, if heavier than air, into a small wide-mouthed bottle.

Since a burning stick is at once extinguished by the gas which sank into the bottle, and lime-water, when shaken through it, is turned white or milky in appearance, it is evident that the gas which is set free by the acid is *carbon dioxide*. Since hydrochloric acid, as its name implies, is made up of the elements hydrogen and chlorine, this carbon dioxide must have come out of the limestone.

Since by heating limestone we get lime out of it, and by treating limestone with hydrochloric acid we set carbon dioxide free from it, we conclude that limestone contains the elements of both lime and carbon dioxide.

We know the elements of carbon dioxide, but not those of lime; so we will try to find the composition of lime. Break into powder a small piece of lime, and add enough hydrochloric acid to dissolve it entirely or partly. Make, at the end of a fine iron wire, a close coil large enough to contain

a drop of the solution, and hold the drop in the flame of the spirit lamp. You should obtain a red flame color.

Note that a drop of the acid in which no lime has been dissolved will not color the flame red; therefore the red color must be due to something in the lime. The substance in the lime which produces the red flame color is called *calcium*. It has been found to be a metal somewhat resembling silver.

But lime is evidently not composed entirely of calcium, for lime is a dull, crumbly substance without a metallic lustre, bearing no resemblance to a metal.

We have seen that lime will not burn any more than carbon dioxide will, and the reason has been found by chemists to be the same. Carbon dioxide will not burn, that is, will not unite with the oxygen of the air, because the carbon in it is already chemically united with oxygen, and so lime will not burn because the calcium in it is already united with oxygen. As lime is a compound of calcium and oxygen, its chemical name is *calcium oxide*.

Limestone, then, is made up of calcium oxide and carbon dioxide, that is, of the elements calcium, carbon and oxygen. Hence the chemical name of limestone is *calcium carbonate*. The first word of this name indicates the metal, the first

part of the second word the carbon, and the ending, *ate*, the third element, oxygen.

Limestone is frequently called carbonate of lime, because it is a carbonate which, when heated, yields lime. The lime of commerce, put up in casks, is obtained by heating some form of limestone—carbonate of lime—in a large furnace called a lime-kiln.

Weigh, or balance on a scale, a lump of lime in the bottom of a bowl. Soak the lump of unslacked lime (quicklime) in water until it ceases to give off bubbles of air from its pores, then promptly replace it in the bowl. The lime will soon become quite hot, but neither free hydrogen nor free oxygen is given off, as you can prove with a test stick.

Allow the mass to become cool and perfectly dry. You will find that this dry slacked lime weighs more than the lump of unslacked lime did.

Since neither the hydrogen nor the oxygen of the water was given off, the lime must have chemically united with some or all of the water itself, that is, with both elements of the water—thus increasing in weight. Water-slacked lime, then, is composed of lime and water chemically united. It is therefore called *calcium hydrate*. You can see that this name indicates the three elements in the water-slacked lime.

Shake a spoonful or two of the dry calcium hydrate through a bottle of water, and let the mixture stand till the water becomes clear. Taste the clear liquid and test it with red litmus paper.

The taste and the change in the color of the litmus indicate that the water has a *base* dissolved in it. This base can be none other than the calcium hydrate, part of which must have dissolved in the water while the rest settled, as you see, to the bottom, because there was not water enough to dissolve it all. The clear solution of calcium hydrate (water-slacked lime) in water is called *lime-water*.

Dissolve a little limestone, lime and water-slacked lime, separately, in hydrochloric acid, and take a flame test in each case. You will always obtain the same flame color. We have said that the metal to which this color is due is called calcium, but you have not seen, and cannot see, the calcium in these three substances, because in each it is chemically united with one or two other elements.

EXERCISES

1. What invisible substance passes off into the air when you heat limestone intensely? Give a reason for your answer.
2. Why will limestone not burn?
3. Which weighs more, the limestone or the lime which may be obtained from it? Why?

XI. THE SOLID CONSTITUENTS OF THE SOIL

Material.—Fine garden soil, black peaty soil or leaf-mould, a pail or basin, wide-mouthed bottles, spirit lamps, lime-water, pieces of glass, lamp chimneys, cotton wool. Specimens of saltpetre (nitrate of potash) and of nitrate of soda.

Put about a tablespoonful of fine garden soil into a wide-mouthed bottle. Add water and mix the soil and water together by stirring. Pour off the muddy water into a large vessel, mix more water with the residue left in the bottle, and pour off the muddy water again. Repeat this process until the water which you pour off is nearly clear.

Let the large vessel stand for several days until the muddy water becomes clear. Pour off the clear water, and set the vessel in a warm place till the sediment becomes dry. Also set aside the bottle in which the water and the soil were mixed, until the part of the soil which remained in the bottle is dry.

Upon comparing the two parts, into which you separated the soil by means of the water—that is, the portion in the bottle and the portion in the large vessel—you will find one much coarser and harsher to the touch than the other. The coarser gritty material resembles sand; the finer looks like impure clay. If your sample of soil yields about equal weights of sand and clay, you

may call the soil a *loam*. If the sand is much heavier than the clay, the soil was a *sandy loam*; but if the clay was considerably heavier than the sand, you had a sample of a *clay loam*.

Pure clay, however, is white, as you may see it in clay pipes and other articles made of white clay. Probably the clay you obtained from the garden soil looks quite dark. If you place a small piece of this dark clay or of leaf-mould in an iron spoon or in a small coil of wire, and heat it in the flame of a spirit lamp, you will find that it will glow as a piece of charcoal would do, and that the black substance slowly burns away, leaving the residue grayish in color.

If you could collect the gas produced by the burning of this dark substance, you would find that carbon dioxide is produced. Both the dark color and the manner in which the substance burns indicates that it contains carbon.

This dark substance which is so abundant in some soils as to make them nearly black is called *humus*. You will observe that it is most evident in soils where large quantities of vegetable matter have been slowly decaying in damp places, as in woods and boggy lands. Humus is largely supplied to gardens and cultivated fields in the form of barnyard manure. This manure is simply vegetable matter — hay, grain, etc. — which the animals did not assimilate.

It must be remembered, however, that humus does not consist entirely of the carbon of the decaying plants. It contains in some proportion the other elements of the carbohydrates and the proteids of which plants are mainly composed. You have not forgotten that carbohydrates consist of carbon, hydrogen and oxygen, and that proteids contain, besides these three elements, two others, nitrogen and sulphur. Some proteids also contain phosphorus. Compounds of phosphorus, called phosphates, are, therefore, necessary constituents of every fertile soil, as also are those compounds of sulphur called sulphates.

The humus in the soil is one source whence the growing plants obtain the nitrogen which they need for making proteids. The higher plants, we are told, cannot use the nitrogen of the humus, nor the free nitrogen of the air. The nitrifying bacteria found in all good soils render the nitrogen of the humus available to the higher plants by using it to form nitrates. The nitrates being soluble in water are absorbed by the root-hairs of the higher plants, and the nitrogen of these nitrates is used by the plant in the manufacture of proteins such as albumin, gluten and legumin.

Examine the dry sand you obtained from the soil. You will find that it is a mixture of different minerals. The commonest mineral in sand

very hard one, called quartz. It is usually white and opaque—when it is called milky quartz—but often it is colorless and transparent, resembling glass but harder. Indeed it will not only scratch window glass, but it is harder than ordinary steel; so your knife will not cut or scratch it.

Try whether you can find any of this hard mineral in the sand. Quite likely you will find other minerals as well. The yellow and red colors you notice in soils are usually due to the presence of iron rust, which is an oxide of iron. A very small amount of this oxide of iron in a mineral or in a soil will impart to it a reddish or yellowish color.

Next examine the clay. It is not pure clay at all, else it would be white. It was pointed out before that it probably contains more or less humus, but humus is vegetable matter. If you could test the particles of clay separately you would probably find more minerals in the clay than in the sand.

Drop a little hydrochloric acid on the dry clay and on the sand. If bubbles of gas are set free in large amount you should put some of the soil into a test tube or a small bottle, treat it with the acid, and empty the gas into a bottle containing a little lime-water. Upon shaking the lime-water through the gas you will at once know what gas it is. This is the gas which the acid sets

free from limestone (carbonate of lime)—a very valuable constituent of the soil. A soil which contains a large proportion of carbonate of lime is called a *calcareous* soil.

We now see that the soil is a mixture of different minerals in a fine state of division, together with a greater or less amount of partially decayed dark-colored vegetable matter called humus. Of course the soil contains many minerals other than those we have mentioned.

EXERCISES

1. Devise experiments to show the difference between clayey and sandy soils in allowing water to sink through them and to rise through them.
2. Try whether humus makes any difference in the power of a soil to absorb or hold water.
3. Find whether nitrate of potash and nitrate of soda are readily soluble in water.
4. Mix a little dry powdered leaf-mould with a teaspoonful of powdered lime. Heat the mixture in a test tube. Smell the escaping gas and note its effect on damp litmus paper. Explain.
5. Try to find how the soils in your neighborhood were formed.

XII. AIR AND WATER IN THE SOIL

Material.—Some garden soil, flower-pots, pickle bottles or other wide-mouthed bottles, an enamelled cup, a small basin, beans, peas or other large seeds, enamelled cups or test tubes, square pieces of glass.

Fill two-thirds of a quart bottle with ordinary soil, and shake the soil down well. Quickly pour enough water upon the soil to cover the surface of it to the depth of an inch or two. How do you account for the large number of bubbles which rise through the water. How could so much air find room in the soil? Add water to the soil till the air ceases to rise. What now fills the space which had been occupied by the air?

Fill two flower-pots with garden soil of the same quality, and germinate a few seeds in each pot. Set the pots in a warm place, and keep the soil moderately damp. When the plants are well started, saturate the soil in one of the pots with water to exclude the air, and keep it saturated by setting the pot in a basin of water. Keep the soil in the other pot slightly moist, but not wet enough to exclude the air. After a time, you should see a decided difference between the plants in the two pots. Describe and explain the difference.

You should recollect here that plants breathe, and therefore require oxygen from the air. As plants are composed of ~~cells~~, we must suppose

that not only the cells in the leaves but those in the roots, as well as in the other parts of the plant, require oxygen. We can see, then, that when the spaces between the particles of soil are filled with water the roots may suffer for lack of the oxygen that they might have got from the air. We will learn that the air in the soil is useful to the plants in other ways. Plants which live under water can obtain oxygen enough, as fishes do, from the air dissolved in the water, but this is not true of land plants.

The last experiment emphasizes the importance of drainage in the case of all soils which are liable to remain soaked with water for a considerable time after rains. The drains carry off the surplus water, and allow the air to penetrate the soil and occupy the spaces between the soil particles.

It seems strange that plants can live so long without rain, in dry soil. If, however, you put very dry soil into an enamelled cup and heat it you will find that water will rise out of it in the form of steam, and condense on a piece of glass laid upon the mouth of the cup.

You have noticed too that when people dig deeply into the earth they sooner or later reach water. Much of the soil water rises gradually, by capillary attraction, towards the surface—as oil rises in a lamp-wick—and supplies the roots of plants, even in very dry seasons, with water from below.

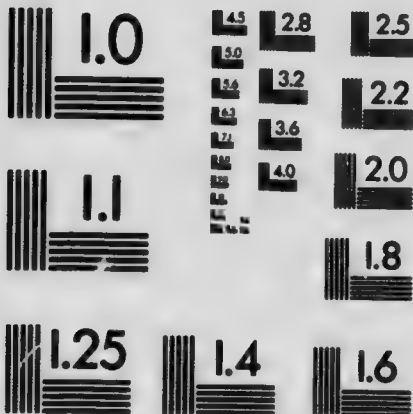
Were it not for this underground supply all vegetation would cease in long periods of drought, for plants require large quantities of water. They need water for making carbohydrates—such as starch, sugar and cellulose—all of which consist of carbon and the elements of water. They need it for making proteins, which contain the elements of water, and for the sap in which the food of the plant must be dissolved. Indeed the plant must take in, dissolved in water, all the food material absorbed by the root-hairs. We know that the plant requires much more water than it retains within its body, for we have seen how rapidly water is given off in transpiration by the leaves of plants.

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(c)



(a)



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(d)



(e)



(f)

BUDDING AND GRAFTING

(a) BUD READY FOR INSERTION.

(c) BUD INSERTED AND WRAPPED.

(b) SLIT IN BARK OF STOCK.

(d, e, f) STEPS IN GRAFTING.

SPRING LESSONS

XIII. THE PROPAGATION OF PLANTS FROM BUDS

FLOWERING plants are usually multiplied by means of *seeds*. Every perfect seed contains a little plant which is capable of developing under suitable conditions of heat, moisture, light, soil, etc., into a mature plant similar to the one which produced the seed.

Many plants can be easily propagated by *buds*. We have seen that a bud will develop into a branch or *shoot*. All that a branch needs, in order to become an independent plant, is a separate root. It already has a stem and leaves of its own.

It is often advantageous to grow plants from buds rather than from seeds. One advantage is that it does not take so long, and another is that it is often more likely that we will get a plant closely similar to the one from which the bud was taken.

Every bud on a tree might develop into a tree by itself, if we could but secure for each bud a root of its own. Four methods of bud propagation are in use: by grafting, budding, layering, and by cuttings.

Cuttings. In making cuttings from plants with soft and juicy stems, such as the geranium, coleus and verbena, short pieces with two or more leaves are cut from vigorous shoots, the cut being made close below a node (the point at which a leaf grows out), and just above which a bud may develop.

The cuttings are prepared by removing the lower leaves, and, if necessary, clipping the upper ones to prevent too great loss of water by evaporation. You remember that plants give off water mostly by the leaves. The smaller the leaf surface the less will be the loss by evaporation.

To keep the cuttings fresh, they are thrown as fast as they are trimmed into cold water. They are at first set out in moist sand in a shallow box. About half the length of the cutting should be covered, and the sand should be firmly pressed about it.

When the new roots are well started, the cuttings should be removed to little pots containing a mixture of sand and fine soil. When a pot is well filled with roots, the plants are ready to be transferred to larger pots. This should be done without greatly disturbing the roots.

The cuttings of some plants strike root well if set in a bottle containing water, so that the lower part of the cutting reaches a short distance below the surface of the water.

Cuttings from plants with hard woody stems, such as the currant, gooseberry and other shrubs, are made during the dormant season, after the leaves have fallen. They may be kept for a long time in a cool place in moist sand or sawdust. They should be "rooted" in moist sand, and when the weather becomes warm they may be at once set *obliquely* in good soil out of doors. Plants such as the blackberry, on whose roots buds will form, may be propagated from *root* cuttings.

Layering. Cuttings are separated from the parent plant before they form roots for themselves. In *layering*, the portion of the old plant which is to be used to form a new one is rooted before it is separated from the parent plant. This is often done by bending down the lower branches into slight depressions in the soil, pinning them there with a forked stick, and keeping this part covered with moist earth. After the root is well developed, the shoot is cut from the parent plant and set out in its permanent place.

If the shoot is too far from the ground to be rooted by the preceding method, roots may be started on the shoot before it is separated from the parent plant by encasing its stem—just above the point where it is to be cut off—with moss or soil kept constantly moist. The moss, two or three inches in thickness, must be wrapped tightly about the stem. If earth is used it may

be enclosed in a cylinder or box held in place by wire or twine.

A cut should be made partly around the branch to hinder the return flow of sap from the shoot which is to be removed. The moss and soil must be kept moist by frequent watering.

It is evident that layering must be carried out in spring or summer.

Budding. In both cuttings and layering, the shoots used for propagation form roots of their own, in the first after, in the latter before, separation from the parent plants. In *budding*, a single bud is taken from the plant to be propagated, and inserted in the bark of another related plant, called the *stock*, which is to provide a support and a root for the new shoot which will arise from the inserted bud. If budding is to be done in spring, vigorous twigs are cut in the dormant season from a tree of the desired variety. These twigs are kept moist by packing them in boxes of moist sand or sawdust until the weather has become warm enough for active growth.

The best *stocks* are one year old from the seed. The stock is prepared for the bud by making a cross-shaped cut through the bark on the north or shady side of the stem close to the ground.

A bud for insertion in this stock is cut out from a twig as follows: Make a shallow cut through the wood and extending upward under the bud,

beginning about one-quarter of an inch ($\frac{1}{4}$ in.) below the bud. Then make another cut crosswise through the bark about one-quarter of an inch above the bud. Lift the edge of the bark here, and carefully peel it back and remove the bud, leaving the wood which you loosened by the first cut attached to the twig. If the inside of the bud, as removed, is hollow, you have spoiled it, for it needs the woody bundles here to unite with the cambium or growing layer of the stock. To insert the bud, raise the edges of the bark at the cross-shaped incision in the stock, and push the bud down under the bark until it fits neatly. Bring the parts into close contact by tying with soft twine or moist raffia.

When it becomes clear that the bud has united with the stock, the binding should be cut, and then, or early in the next season, the stem of the stock should be cut off a short distance above the bud. It is well to cover the cuts with wax.

Budding is sometimes done early in the fall. In this case the leaf blades below the buds should be cut off before the bud is inserted in the stock.

The bud will develop into a stem bearing branches, flowers and fruit. Although this new stem derives its water and mineral nutrients from a stock of a different variety, yet the fruit will be of that variety from which the *bud* came.

Grafting. In grafting, a *portion of a branch* (called the scion) from one tree is made to grow on the *root or stem of another tree* (called the stock). The stock is usually grown from the seed and should be of a hardy sort, while the scion is taken from a tree of a choice variety.

The scion will develop into a large stem with branches. It uses the root of the stock as though it were its own, and derives its water and food materials from the soil *through the stock*. Its growth, however, is due to the multiplication of its own cells by division, and the new cells have the same powers and properties as the cells of the tree from which the scion was taken. Consequently, the scion produces fruit of the same choice variety as its parent tree.

In *root-grafting*, the scions may be cut in mid-winter from the last season's growth of the branches, and stored in cool moist sand till the end of winter. They are then grafted on to the root, or short pieces of the root, of a young stock. In the case of the apple the stock should be about two years old.

There are different ways of setting the scion upon the root of the stock. In the *tongue-graft* the top of the root and the lower end of the scion are cut off evenly at the same slant, and a thin wedge or tongue is cut out of each near the middle of the slanting surface. The scion is then fitted

'closely on the stock, so that the inner bark of the one exactly meets that of the other in at least one place. The joints should be wrapped tightly with strips of grafting cloth about half inch wide. The grafting cloth is made by covering strips of cheese cloth or muslin with a mixture of four parts of resin and one part of beef tallow melted together. Exposed cut surfaces of the scion should be protected by covering them with grafting wax made by melting together four parts of resin, two parts of beeswax and one part of tallow.

Scions may be grafted on to the stem of the stock in a similar way. When the diameter of the stem or branch of the stock is greater than that of the scion, it is usual to make a *cleft-graft*. This is done by splitting the cut end of the stock and inserting two scions. The scions are cut so as to form a slender wedge at the base. Care must be taken to bring the *cambium layer* (between the bark and the wood) of each scion into close contact with that of the stock in at least one point. All cut surfaces should be carefully protected by grafting wax.

Old fruit trees may be used to produce new and choice varieties of fruit by grafting (*top-grafting*) on to their branches short twigs from the desired varieties. A number of varieties may thus be grown on one tree. Top-grafting is

done in spring after the buds begin to swell. The scions must be kept moist and dormant till the time of grafting.

XIV. IMPROVEMENT OF CULTIVATED PLANTS

It is thousands of years since men in various parts of the world, emerging from the savage state, began to cultivate some of the wild plants which produced fruits or seeds suitable for human food. In the course of ages, by careful cultivation and selection these wild plants have been wonderfully improved.

In some cases the wild parent plants can still be found and recognized; in other cases they seem to have died out or else bear such a slight resemblance to their cultivated offspring that we cannot be sure of the relationship. The wild apple of the old world, from which our cultivated apples have sprung, is a very diminutive fruit. The improvement in size and quality of cultivated roots and tubers, not to speak of the common grains, has been equally remarkable.

There are very definite limits to the capacity of plants to respond to our efforts to change them. I should say that there is little likelihood that we shall ever be able to grow grains of wheat, for instance, as large as apples, or apples equal in size

to pumpkins. Still there is no reason for thinking that the limit has yet been reached. Indeed, as our knowledge of plants increases, so should our power to develop more productive forms of cultivated plants.

Three principal methods of plant improvement are in use. The first method is the selection of the best seeds from the strongest and most desirable plants; by constant selection of the finest seeds a great gain, both in the quantity and quality of the products, may be secured. This is, however, a slow process, giving uncertain results. In order to maintain the improvement which may be reached by this method it is necessary to keep on selecting the best seed year after year. If this is not done, many seeds from the poorer varieties will be sown and their offspring will gradually crowd out the better kinds of plants.

A second and accurate method consists in selecting a single plant which shows desirable qualities in a higher degree than do the individual plants surrounding it. Seeds from this plant are sown by themselves. If these seeds produce plants having the same desirable qualities as the parent plant, seeds of this generation are sown by themselves, and the process is continued, until a sufficient quantity for practical purposes is secured. A variety thus obtained will continue to breed true from the seed.

The third method depends on the production of *hybrids*. We have learned that every flowering plant is developed from an egg-cell, and that this egg-cell is formed by the union of a germ-cell which descends the pollen tube with another germ-cell in the ovule (the young seed). If the pollen grain comes from a plant of a different variety or species from that of the plant which it fertilizes, the egg-cell will develop into a plant which will probably resemble in some respects each of the two plants which had a share in producing the egg-cell.

It is evident, then, that if we find two related plants, each of which has some desirable characteristics not possessed by the other, we may succeed in uniting these features in one plant by transferring the pollen of one to the stigma of the other. If *cross-fertilization* occurs, the embryo may develop into a plant resembling in some respects each of the parent plants. This new plant is called a *hybrid*. Hybrids of the first generation do not breed true. If, however, they show desirable combinations of the qualities of the parents, they may be perpetuated by means of cuttings or buds.

In the next generation, a certain proportion of the different kinds of plants obtained will show fixed combinations which can be preserved by sowing the seeds of each type separately.

XV. A LESSON ON TILLAGE

Country boys and girls are more or less familiar with the various methods of cultivating the land, and most city children must have seen these operations going on, if only from a railway carriage. Let us consider the use of all this hard work.

The plough and harrow are used in preparing the soil before the seed is sown. The plough goes deep down into the ground, turns the upper soil over and pulverizes it somewhat. It buries manure, weeds and stubble. The harrow with its many teeth pulverizes the soil more thoroughly if not so deeply.

This preparatory cultivation, if well done, is of great use in several ways. It exposes some of the lower soil to the action of the air. By loosening the soil it makes more room for air and water, both of which are needed by the roots of the plants. By breaking the soil up into separate particles it increases greatly the amount of surface exposed to the air and water. The air and water act chemically on substances in the soil, so that more soluble substances necessary for the growth of plants are formed there, and dissolve in the soil water. The loosening of the soil makes it easy for the rootlets to penetrate in all directions in search of food materials. Stirring the soil also permits the surplus water after rains to drain downward

into the earth. In this way ploughing aids in warming the soil. Wet soils are always relatively cold, for the heat of the sun is largely used in evaporating the water instead of in warming the soil.

In all cases in which the young plants are far enough apart to allow of it, cultivation to the depth of from two to four inches should be carried on throughout the season, or till the size of the plants interferes with the process. Repeated cultivation is necessary to kill the weeds and to maintain a loose soil mulch, which hinders the evaporation of water from the soil below during dry weather, and retains it for the thirsty rootlets. Stirring the surface soil breaks up the small continuous spaces through which the water from below would rise by capillary attraction, so that the water cannot escape so rapidly into the air, and thus be lost to the roots of the plant.

The roller is often used to crush clods of earth. It is useful in loose soils for compacting the earth somewhat. This helps to form small tubes in the loose soil, through which the water from below may rise to supply the roots of the young plants.

In a small garden the spade may do the work of the plough, while the rake and the hoe are used instead of the harrow and the horse cultivator. The soil about the seed, and about the little plants which are being set out in the garden, may be

compacted with the back of the hoe or by the pressure of the feet or hands of the gardener, thus bringing the soil particles into close contact with the roots of the young plants.

XVI. ROTATION OF CROPS

Few soils will produce a good crop of the same plant year after year for a long period. To keep up the productiveness of the soil it is necessary to change the crop, that is, the species of plant, from time to time.

It has been supposed that the failure of a soil after a time to produce good crops of the same plant—wheat for instance—continuously, is because some of the substances in the soil which are essential to the satisfactory growth of the plant have been exhausted, or at least so greatly reduced in amount that there is not enough left to permit of a good yield. Some investigators claim, however, that the failure of the crop in such cases is often due to the fact that the roots of plants excrete into the soil substances which are poisonous to the plant which produces them.

A change of crop may be needed in order that weeds which have established themselves in the soil may be destroyed. For this purpose a crop that can be cultivated throughout the summer

should follow one which did not allow of continued cultivation.

Again, some plants send their feeding roots more deeply into the soil than others, and draw their food from a greater depth. Such plants may be planted in succession to shallow-rooted ones.

Clover is very largely employed in keeping up the supply of nitrogen in the soil. If you dig up a clover plant (and the same might be said of peas, beans, and any other plants of the legume-bearing family), you may find on its rootlets small nodules or tubercles. Each of these tubercles has been found to be the home of a colony of bacteria. These bacteria have the power of extracting nitrogen out of the air which occupies the spaces between the particles of soil, and of causing this nitrogen to unite chemically with other elements. The clover plant then absorbs this nitrogen compound out of the tubercles and uses it in the manufacture of proteins, which, as you know, are compounds containing nitrogen. So the stem and roots of the clover contain a good deal of combined (*fixed*) nitrogen which was obtained directly from the air by the bacteria of the tubercles. Consequently, when the whole clover plant or its roots are ploughed under they enrich the soil with a considerable amount of nitrogenous matter; hence it is that clover has come to find a place in most rotations.

Other plants besides clover are sometimes grown, to be ploughed under while green that they may by their decay add humus to the soil.

Different rotations are adopted to suit different conditions of soil, climate and market. These are some common three-year and four-year rotations:

- (a) Wheat, clover, potatoes.
- (b) Clover, corn, wheat.
- (c) Clover, corn, potatoes, wheat.
- (d) Corn, wheat, clover, grass.

Each farmer, however, must determine for himself the rotation which is most suitable for the different soils found on his farm, and for the various crops he finds it most profitable to raise.

XVII. HOME AND SCHOOL GROUNDS

A home or a school in which love and order reign is a happy one, no matter how bare its walls or how barren and brown its surroundings. Yet even a happy home or school is made more attractive, and dearer to the hearts of its members, if the grounds about it are tastefully adorned with trees, shrubs, flowers and grassy lawns. The plainest cottage is made home-like by a few vines creeping over its door and roof, and a few flowers blooming beneath the windows.

In beautifying the home and school grounds nature will be found the best guide. In the woods, along the streams, about the borders of the meadows, here and there, may be seen natural groupings of trees and shrubs, ferns, and low flowering plants, which impress themselves on our memories because of their beauty and fitness. These natural pictures will furnish material for an imaginary picture which may be realized about the home and school.

A grassy lawn will form the basis of the plan. If the space is small, the trees must be planted in straight rows, or singly in the corners of the lot; but if there is room enough, it is better—because more natural—to plant them in groups. Trees should, as a rule, be set 20 or 30 feet apart; but they may be planted more closely at first, with a view to thinning them out when they become large enough to interfere with each other's best development. If possible, space should be found for a few fruit trees belonging to varieties hardy in the district. A row of evergreen trees will often afford welcome protection from cold winds.

Shrubbery may be worked in around the lawn, in vacant nooks and corners, and at bends in the paths. Suitable spots can be found for planting ferns from the woods, and some of the wild flowering plants which adorn the meadows and groves in spring and summer. On either side of the

pathways may be set such cultivated perennial plants as lilies, irises, peonies, dahlias, etc.

If young trees are transplanted from the neighboring woods they should be taken up carefully, so as to save as many rootlets as possible. The holes in which to set them may be dug in advance, so that the trees may be set out at once. If trees are obtained from a nursery they will probably be in good condition for planting out when they arrive. It is very important that the rootlets should not be allowed to become dry.

In most cases the tops and branches should be cut back to balance the loss of roots. If this is not done there will be so many leaves produced that the water will evaporate from the leaves faster than the roots can supply the loss, and the tree will dry out and die.

The roots should be covered with good soil, well shaken and packed down. Before the last of the soil is put in, saturate the earth about the roots with water. The last layer of soil spread on should be left and kept loose to hinder evaporation from below. In dry seasons the soil about the roots may occasionally need to be saturated with water. When necessary a guard of stakes or palings fastened together should be set around each tree.

Children would find it very interesting to grow some of the native trees from seed, in window boxes, or in plots out of doors, to be afterwards

transplanted in the home or school grounds or along the road.

As the trees grow they may need occasional *pruning*. Trees produce so many buds that the number of branches is liable to become too great. In the competition between the branches for food and light, those which gain the lead do not always add to the beauty or to the productiveness of the tree; hence the advantage of judicious pruning. You should never, in pruning, cut off or cut back a branch until you have considered what advantage will follow, either in stimulating the growth of other branches or in improving the form of the tree.

We have considered the beautifying of the home and of the school grounds together, for the same principles apply to both. The school takes the place of the home for several hours each school day. The school should aim to be an ideal home for the children for that time, but as there are usually more children in the school than in the family home, the school grounds need to be larger—much larger than they usually are.

In planting trees and shrubs on the school grounds, the different kinds of native trees should be represented as far as space permits. Some trees and shrubs whose fruits afford food for birds should also be planted. A well-selected variety of trees and other plants will make the school grounds a rich field for nature studies.

PRAIRIE PROVINCE AGRICULTURE



HEADS OF RED FIFE WHEAT.

FIRST YEAR

I. WHAT IS AGRICULTURE?

WHAT do you understand by the term "Agriculture"? Most boys and girls, and in fact the greater number of grown people, would answer this question by saying: "Agriculture is the business of growing crops and feeding them to horses, cattle, sheep, swine and poultry for the production of meat, milk, wool and eggs." Many of the products of the farm, such as wheat, barley, flour, milk, fruits and vegetables are sold to provide for the needs of people who live in cities and towns, and also to furnish food for the domestic animals kept there. All this is agriculture, but it involves much more, for it is the main source of wealth of our vast new country—the Prairie Provinces—and indeed of Canada generally.

Climate, Soil and Seed. In order that agriculture may be carried on successfully, there are three essential things that must be carefully considered and attended to,—climate, soil and seed. These are so important that the good farmer must give much consideration to each of them by itself, that his efforts in caring for his crops may lead to the most profitable results. Climate itself is of

great importance, for it has to do with sunshine, light and warmth, cold and frost, air, dew, drought and moisture. You have all seen a delicate little plant trying to grow in a shaded place. You would not give much for its chances of living, much less for its ability to bear a well-filled head of wheat. You have seen, too, the crop blighted by the frost that came a few nights too soon. You have noticed the withering effects of drought when the hot winds from the south-west fairly scorched the fields of growing grain that had not enough moisture at its roots to tide it over this trying time.

The Soil. What is the soil? You say, "Soil is the fine, loose material on the outer surface of the earth that affords a home for the plant," and you are quite correct in your answer. The soil gives the plant a place on which to stand; it gives it certain kinds of food and affords it a chance to grow up straight. Hence, the soil plays a very important part in the growth of plants. To find out what it does and how it does it, is a very interesting study. As we proceed with our work, we shall discover how necessary a soil in good condition is to the proper growth of plants.

The Seed. You have already learned some interesting things about the seed in your Nature Study lessons. You will remember that it is a little plant lying asleep, packed around with nourishing foods and protected by a light outer covering

or seed-coat. The little sleeping plant is lying ready to be awakened when placed in a warm seed bed and watered by genial life-awakening showers.

Now we can see from what has already been said, that agriculture is a very important occupation, and that there are a great many things that must be known about it, if we are to make it a successful life work. The tailor serves an apprenticeship and studies how to cut, fit and sew before he will attempt to make a neat fitting, durable suit of clothes for you. You would not think of calling in a doctor to attend your father or mother, who had not been educated in a college where he could learn about diseases and how to treat them, in the very best way. Now, don't you think, since agriculture is such an important business in our country, that everybody should know something about it, and that those who are going to follow that business for perhaps a lifetime, should learn just as much as they can about the principles that underlie its successful workings? We should like to see every farmer doing his work in the most successful way, for in so doing he will get the greatest amount of real happiness and obtain the best results for his labor.

FOR THE TEACHER

The teacher should procure the reports of the different Provincial Departments of Agriculture as well as that of the Dominion Department at Ottawa. From these much

interesting information can be gleaned. The teacher will thus be in a position to impart to his pupils correct ideas of the systems of agriculture followed in the different parts of Canada. When this has been done, the general agriculture of other countries may be studied. The pupils should then be asked to answer such questions as the following :

How does the agriculture of Manitoba compare with that of Ontario? Alberta with that of British Columbia? Saskatchewan with that of Nova Scotia?

II. THE SOIL

Its Nature. Thousands, yes, tens of thousands of farmers from all the best parts of the world have been attracted to the Prairie Provinces on account of their great stretches of fertile soil. Now, "What is this soil?" is a question that naturally comes up in our minds. Almost anywhere we go, we can with little difficulty dig down into the fine, loose material that covers the outside of the earth. In some places it is quite shallow, and in others we might dig or bore for hundreds of feet. This fine, loose covering is called soil. It is always found resting upon a foundation of rock. In agriculture, we think of the soil as those five or six inches of loose material in which plants grow. Of course, plants send their roots away down for several feet into what is known as the sub-soil, or the soil lying immediately under that in which seeds are sown.

Take a handful of soil from the top three inches of a cultivated field and spread it out on a piece of white paper. Look at it carefully and note its color. It may be black, brown, red, blue or white, or shades of these. The soil gets its color from certain ingredients, and we shall see later on that color is a very important feature of the soil, because it indicates, in a measure, its fertility and other important qualities it possesses.

Now, examine it closely to find out what you can about the size of the parts of which the handful is composed. You will see lying close to the paper and adhering to it, very fine dust particles, as fine as the finest flour. They are all separate from one another. These are so fine that you cannot tell their size or shape with the naked eye, nor can you weigh one of them with the most delicate scales. There are single pieces that are much larger, and you can see their shape, measure their size, and determine their weight. Whether fine or coarse, these single particles are called soil *grains*. Look again and you will find a number of the finest grains all sticking together, forming a little lump many times larger than a grain, but still quite small. This little lump is called a *granule*. When the surface soil of the whole field is composed of fine granules, it is said to be in good *tilth*. Then you will find larger lumps made up of many granules. These, if

large enough, are called *clods*. You may also find some pebbles or small stones. Besides these you will find small bits of roots, parts of leaves and stems of plants. These we call *fibre*. When these parts of plants decay and lose their shape and much of their weight, the part that is left is black in color. Animal matter, too, decays and returns to the soil along with vegetable matter. Partly decayed vegetable and animal matter in the soil is called *humus*. Now, you may examine it for weight. If it contains many stones or is composed largely of sand, it will be heavy. If it is almost wholly made up of clay, it will be medium, and if it contains much fibre or humus, it will be light, so far as the scales will indicate.

EXERCISES

1. What do you understand by the terms soil, subsoil, humus, fibre?
2. Separate from your sample a soil grain, a granule and a clod.
3. How would you distinguish between a soil grain, a soil granule and a clod?
4. What is meant by tilth?
5. Is the sample of soil you have examined in good tilth? Give reasons for your answer.
6. The size of the granules indicates the texture, whether fine, medium or coarse.
7. Determine the texture of soils in different fields at different times of year.

III. THE SOIL—ITS USES

If we look about us in the fields and gardens we see plants—many of them—all standing erect firmly attached to the soil. Observe them carefully and you will find that the soil affords the plant a place to attach its roots and hold on firmly, so as to be able to send its stem straight up, where its leaves can come in contact with an abundance of air and sunlight.

One of the greatest uses of the soil is its ability to hold moisture and furnish it to the plant when it needs it. And one of the greatest triumphs of modern agriculture is that of having solved the problem of how to manage the soil so that it will do this work sufficiently well to ensure the farmer a good return even in the driest years. We build cisterns and tanks in our houses and barns for the purpose of catching and storing water for the use of the home and the stock. Now, the soil acts as a great storage tank in which water from rain and snow is caught and held for the use of plants from the time the seed is put into the ground until the plant has ripened its fruit or is ready to harvest. You will see, as you study further on, that every farmer who is on a fairly good farm, has it in his own power to produce good paying crops, and I am sure you will all agree that every farmer ought to know how to do this.

Burn a dry plant and you have left only a small amount of gray ash. If you weigh a dry plant and then weigh the ash obtained from it, you will find that the ash is about five per cent. of the dry weight. Now, all of the ash material of the plant was taken from the soil in which the plant grew. It was, of course, in solution in the water that was taken in through the roots. The soil, then, must furnish certain food materials to the growing plant.

You have learned in some of your earlier studies about *bacteria*. (See Nature Study, Second Year, Lesson VII.) Numbers of these useful and helpful bacteria live in the soil when it is in a condition to afford them a comfortable home. Most of these numerous families, when they find their environments congenial, work in the interests of the farmer. They make and gather foodstuffs for the plants that are growing in the soil. You can readily understand how important this is, for plants cannot move about in search of food as animals can. Cattle, sheep, horses and poultry roam about in search of food and water, but plants can get only such soil food as is brought within reach of their roots. Here, again, is another most important fact that has been ascertained for the farmer. The soil is a laboratory in which millions of little workers are busy turning out products that are either useful or harmful to

the growth of the farmer's crops. He must know how to make the conditions in the soil the most congenial for useful bacteria to live in, so they will thrive and multiply and work for him. Such conditions will be uncongenial for harmful bacteria.

EXERCISES

1. How do plants get food from the soil?
2. What name is given to that part of a plant which is left when burning has taken place?
3. In what ways does the soil serve the plant?
4. Plant a large plump grain of wheat two inches deep in a can of moist soil, first punching a few holes in the bottom of the can for drainage. Keep it watered till the plant has headed out. Cut the can away and wash off the soil from the roots. Place the roots in a pail of water. Observe how they filled the soil. The roots of one mature wheat plant laid out end to end will reach from 1,000 to 1,700 feet.

IV. THE SOIL.—ITS ORIGIN

We are all interested in knowing something about the beginnings of things. The soil of which there seems to be such immense quantities spread all over the continents, had a beginning. It did not always exist in its present form. Countless ages ago the outer crust of the earth was composed of rock. A great many changes have taken place in its structure since then, and it is these changes that makes it possible to carry on the different

operations of farming to-day—especially that of crop growing. The soil is composed of two materials—broken-down rock and a small amount of partly decayed vegetable and animal matter called *humus*. Now, the question is, how has the solid rock been transformed into soil?

Many natural forces have been at work for countless ages. While each one may seem to us small in itself to accomplish so much, yet we cannot help but admit that it is possible for the smallest agencies to accomplish great results if they are persistent through a long period of time.

Examine rocks in the fields where it is possible, and see for yourselves that even now the rocks are breaking down from one cause or another. The sun's heat has been instrumental in crumbling rocks that are made up of materials of different degrees of hardness. Stones and iron and many other materials expand when heated. Some substances heat much faster than others. Some stones, according to their make-up, heat much faster than others and so expand more rapidly. If a rock is composed of several kinds of rock materials, we can readily understand that when heated there will be uneven expansion, and following this a consequent crumbling and breaking down.

Then there is the frost of winter—a most powerful agent in the undoing of solid rock. All of the

rocks, though they may seem perfectly compact, are more or less pervious to both air and water. Even the hardest granites will admit both. When 100 cubic feet of water freezes it makes a cake of ice measuring 109 cubic feet. You can readily understand, then, that when all the tiny particles of water inside the rock have frozen there will be a tremendous pushing against the adjoining particles of rock. And you all know what happens to a pitcher when water freezes solid in it. It breaks; and so does the rock, into innumerable small pieces. And again these pieces are broken still finer by the same agent, frost. Soak a clod of earth in water and subject it to the action of frost. Study this in the spring and observe the effects.

The wind drives these broken pieces of rock with great force against other rocks, and gradually but surely grinds them to a fine powder. The wind has been blowing for ages and its wearing effect upon the rocks is to be seen in the soil that has been left as a result of its work.

Long ages ago all the northern part of the North American continent was covered at one time or another by great fields of compacted snow and ice called *glaciers*. These kept moving southward and south-westward, extending as far as latitude 40° north, where the weather was warm enough to melt the ice. Melting took place, of course, much farther north as the snow fields receded, leaving immense

lakes and rivers. The valley of the Red River in Manitoba, including the level stretches on either side for miles, was at one time the bottom of one of these lakes. Now, when these fields of ice and snow were slowly but gradually moving southward, they carried along immense boulders, imbedded on the under surface, and as they ground over the rock, they, as well as the rocks underneath were crushed to fine powder which we now have as soil.

Water itself is a powerful solvent. All stones, as we have said, absorb water. Some ingredients of the stones are readily soluble and, in time, much of their substance has been washed from them and they have been left in a honeycombed condition.

The air, too, or at least the oxygen and the carbonic acid of the air, have a corroding effect upon many rocks, and gradually cause them to crumble to dust and form soil.

Animals have quite a part in the making of soil. You have seen the bits of gravel in the crops of poultry, all ground smooth. Earthworms pass large quantities of soil through their bodies, and while in the process it is ground finer and finer. Darwin estimated that the earthworms in one acre of soil passed ten tons of earth through their bodies in a year. Burrowing animals such as the gopher, prairie dog, ground hog and others, have a part in the making of soil. And everywhere that

animals walk or climb over rocks they cause a certain amount of grinding that results in soil formation.

Plants are also active agents in this work. Lichens and mosses find a foothold on rocks. Their roots eat into the rocks and waste them away. Seeds of trees find a lodging place in a crevice and sprout there. The ever-enlarging roots pry the rocks apart, and in this way assist in their gradual and sure breaking down into smaller pieces, to be acted upon in turn by the other agents mentioned above.

EXERCISES

1. Take two pieces of rock and rub them briskly together. What do you observe?
2. Soak a piece of limestone in warm water and place it out doors on a cold day in winter, long enough to freeze the water inside it. Bring it in and thaw it out on the stove or furnace. Soak it again and repeat the freezing. Observe the effects.
3. What happens to a grindstone that has been long in use?
4. If there are any rocks in your neighborhood, examine them for lichens and mosses.
5. Name and explain the work done by different agents in forming soil.
6. Observe the work of gophers, ground moles and earth-worms.
7. Name the kinds of soil in your neighborhood and tell how they were formed.

V. SOILS—HOW THEY ARE DISTRIBUTED

A careful examination of the soils in a neighborhood, or even on our own farm, will show us that the soil is not all the same. One quarter-section or a part of it may be one kind, while just near, it is something altogether different. Here in this *pocket* is coarse, loose material made up largely of rounded pebbles and shells with a little finer soil intermixed, and beyond is something very fine and very sticky when wet. We wonder how this has happened. Now, these soils were made perhaps hundreds of miles away and were transported from their place of origin by various agencies—the same agencies, in fact, that assisted in forming soils have had much to do with their distribution.

Notice the rivers and creeks running through the prairies, for example the Assinboine, Red, Souris, Saskatchewan, and any of the creeks that may be near you. Take a glassful of the water and allow it to stand for a few hours, say twenty-four. What happens? If you have delicate enough scales convenient, you can calculate how much soil is being carried down the stream in every ton of water. The waters of the Mississippi and Missouri rivers and many of their branches, are heavily charged with *sediment*. These rivers are continually wearing away their banks and carrying the wornout soil further down the

stream, to be deposited far from its place of origin. Mountain streams during freshets bring down the finely worn particles from the hillsides and deposit them somewhere down their valleys. You have seen hillsides in your own neighborhood worn away and the soil carried off during spring freshets or June and July rains. The Red River Valley soil was transported by water and so was most of our soils further west. Your geography will give you many illustrations where large tracts of land, such as the deltas at the mouths of the Mississippi and Amazon rivers, are even now being built up in this way.

The wind is very active too, in the transportation of soils. You have heard of the sand storms of the deserts. So thick is the air with dust, that man and beast can scarcely live in one. You have seen the soil drifting from your summer-fallows in the spring. Some of you perhaps have had your grain fields nearly ruined by one of these dust storms. You know, too, how weed seeds of all descriptions are carried along with the soil and left far from their place of origin and deposited on some farmer's clean fields. There are in some places long stretches of hills made entirely of wind-blown soil. There are no rocks in these hills. You can cut their sides down straight and the soil will stand up like walls. Wind-blown soil, such as has been described, is called *loess*. In China there are

such hills where the soil is from a hundred to two thousand feet in depth. Loess, or wind-blown soil, is found along the Mississippi and Missouri rivers. We have here on the prairies much soil that was first carried by water and then afterwards heaped up in ridges by the wind.

The force of gravity causes soils to roll down hill. Possibly the particles have been started by the falling of a rock or tree, the tread of an animal, the jar of a passing train, a snow slide or any one of many other similar causes.

Animals that assisted in forming soils also share in carrying them from place to place. Horses and cattle and other animals carry soils and weed seeds on their feet from one field to another. Worms, ants and burrowing animals bring soils from lower depths to the surface.

Then, too, soil is distributed on wagons and railway trains for long distances in cars. Sacks and barrels of soil *inoculated* with alfalfa bacteria are taken from infected to uninfected districts, sometimes hundreds of miles away. In some of the cities and towns situated in the heavy clay belts, trainloads of vegetable and sandy loam have been imported for the purpose of making good lawns and gardens and for the purpose of putting around the roots of young trees when setting them out, to ensure their living. The soil taken from the bottoms of cellars and wells is used to fill up hollows.

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PLOUGHING A SUMMER FALLOW FOR THE FIRST TIME ON JULY 23RD.
 Note the height of the weeds; many of them have ripened and scattered
 their seeds, and at the same time they have pumped moisture out of
 the soil, making it so dry that it will not pulverize.



ANOTHER VIEW OF THE SAME FIELD AFTER IT WAS PLOUGHED,—
 VERY BAD WORK.

A poor crop is a sure result from such methods.

EXERCISES

1. Explain how water transports soil.
 2. Of the agents named, which do you think has been the most active in moving soil? Give reasons for your answer.
 3. Should we aim to assist or hinder these agents now in transporting soil? Give reasons for your answer.
 4. Put a couple of handfuls of soil in a clear glass quart jar. Fill the jar with clear water. Put on the cover and shake vigorously. Let it stand and observe the particles settle. Which settle first? Which last? How long until the water is clear again?
 5. Take a jar of water from a muddy stream and make similar observations.
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VI. SOILS—KIND AND NATURE

Soils are classified in many different ways, but we shall speak in this study only of such kinds as come up in everyday agriculture on the prairies.

In some places we have soil made up of large single grains, the whole taking on a sort of light reddish appearance. Many of the grains resemble glass. This is called *sand*. It was formed in the breaking down of a particular kind of rock. Sandy soil usually contains some finer material known as *silt*, and possibly a small amount of humus, already mentioned in a previous study. (Lesson II.) Sandy soils are heavy, so far as actual weight is concerned, for a cubic foot will

weigh about 105 pounds. But because its particles lie loosely together and because it is easy to work, it is called *light soil*. Its capacity for holding water is small and it also parts with its water very easily. For this reason, together with the fact that it absorbs heat readily, it is called *warm soil*. Because of its small capacity for holding water and because of its parting with it so readily, it is very liable to *drouth*. It is a soil, too, whose fertility is soon exhausted, and we say of such a soil that it will *run out* quickly.

We have another kind of soil that is composed of the finest sort of particles, made, it would seem, by intense grinding of rock. This soil when wet is very sticky and when dry bakes in hard cakes. It is, on account of its sticky qualities, a very difficult soil to work and is for this reason termed a *heavy soil*, though a cubic foot of it when dry will weigh only about 70 pounds. On account of its very fine particles it has a great affinity for water, and can hold large quantities. It does not part with its water readily, and for this reason, if well worked, is a good drouth resister. Because of its great capacity for water it remains cold and oftentimes sour, until it has been underdrained. It requires good management to handle to best advantage sandy or clayey soils and maintain either in a high state of productivity.

A sandy soil has more sand and less clay, while a clayey soil has more clay and less sand. A loam is a mixture of clay, sand and humus in such proportions as to make a friable, easily worked soil. Loamy soils are usually spoken of as medium light, warm, *quick* soils. Quick means that you can get to work on them early in the spring and that they will hasten crops to maturity, thus avoiding early frosts.

Humus soil is that which consists largely of decayed or partly decayed vegetable matter. This is more properly called *peat* or *muck*. It is found in swamps and marshes, and being very porous holds water like a sponge.

Gumbo is a combination of clay and other materials that form a sticky, stubborn mass. Sometimes it is on the surface, but more often it forms the immediate subsoil. When ploughed, it turns up in the form of sticky, rubber-like ribbons, and, if wet at all, bakes into brick-like clods. It usually grows good grass, but is most unsatisfactory for grain farming until it has been *weathered*. In most gumbo sections it is very difficult to get good water except that which is caught from rain and snow.

Alkali soils are caused by the presence of sodium *salts*. (See Nature Study lesson, for *salt*.) There are two kinds of alkali soils—black and white. White alkali is caused by the presence

of sodium carbonate. Black alkali is composed of sodium carbonate, a chloride, and sometimes borax and Epsom salts. We are quite familiar with the white alkali of the sloughs. We do not like these spots in our fields. They interfere with the work and they diminish the total yields. In another lesson we shall tell how they are sometimes treated so as to make them productive.

Then we have gravelly soils, which are made up very largely of coarse pebbles, shells, sand and silt, with small amounts of humus. These soils are poor water holders, and hence poor producers. One should be careful in selecting a farm to see that the subsoil is clay and not gravel or sand, for in this difference will lie success or failure in growing crops. We must choose a soil that will hold water or we cannot expect it to tide over dry times in the crop-growing season.

The subsoil is that soil lying immediately under the furrow slice. Sometimes it is of such a nature as to be spoken of as *hardpan*. Hardpan is formed of soil grains cemented together by solutions from the surface soil that have been washed down by rains. The mass hardens almost like stone, so that water can soak into it with difficulty. It is for all practical purposes impervious to both air and water.

EXERCISES

1. Collect samples of different soils and subsoils on your own farm or in your own locality, and have them classified at school.
 2. Weigh out a pound of wet sand, clay and loam. Dry each in an oven and then weigh. Calculate the per cent. of weight lost. What has gone from the soil?
 3. Observe crops growing on light and heavy soils as to stand, quantity and quality of product.
 4. What are the advantages and disadvantages of a warm soil?
 5. Explain the terms gumbo, alkali, humus and loam. Find samples of each.
 6. When possible observe the nature of the different layers of soil taken out of a cellar or well.
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VII. THE SOIL—ITS CHEMICAL PROPERTIES

In another lesson (Nature Study—First Year, Lessons XIV to XXI), you have studied something about elements and compounds. You learned that water is a compound made up of hydrogen and oxygen; that sugar and starch are compounds made up of carbon, hydrogen and oxygen; that saltpetre is made up of potassium, nitrogen and oxygen; and that bluestone is a compound consisting of copper, sulphur and oxygen. You learned that each one of these several things, such as nitrogen, oxygen, hydrogen, sulphur, potassium, copper and many others, about 80 in

all, are called elements. You have learned, too, that about five per cent. of the dry matter in plants is composed of ash, which is taken from the soil in solution by the roots. Now, this leads us to inquire as to what extent the soil is able to supply mineral or ash materials suitable for plant food. In other words, what are the chemical properties of the soil so far as it is concerned with the growth of plants?

Take up a handful of black prairie earth and look at it. You can tell at once its color, weight, *texture*, warmth and dryness. You can tell its kind, whether sand, clay, loam, humus, gumbo, alkali or gravel. But you cannot tell of what compounds it is composed or what elements make up these several compounds. It takes the plant and the chemist to do this. The soil is not an element, nor is it a compound, but it is a mixture of a great number of compounds, only a very few of which are of use to plants. The plant requires from the soil phosphorus, potash, iron, magnesium, sulphur and lime, as well as nitrogen, which does not appear in the ash. These are, as we have already noted, elements, but the plant cannot take them from the soil as such. The elements must be held in compounds and in such compounds as are soluble in water, for the roots can take in only such food as can enter with the soil water.

The farmer does not have to concern himself about magnesium, sulphur or iron, for almost any soil has sufficient quantities of these elements to supply our crops with all their needs in so far as these are concerned. Nearly all of our prairie soils are fairly rich and most of them are very rich in nitrogen and phosphorus. Potash and lime are held perhaps in smaller quantities. The continuous cropping, together with poor or careless methods of tillage, or an insufficient supply of moisture, render these essential plant foods very scarce in some soils.

Nitrogen. This element is found almost wholly in the humus, but it has to be changed in the soil to *nitric acid* and then to a *nitrate*, in order to be *dissolved*. It is well to remember that all nitrates are soluble. It is as a nitrate that nitrogen enters the roots as food for the plant. Now, since humus is one of the great sources of nitrogen in the soil, it is necessary that a farmer put forth intelligent efforts to keep up a good supply of this ingredient. Without nitrogen in the soil it is impossible to raise either quantity or quality of wheat and other grains. Good tillage and moisture are necessary in order that the changes that result in the formation of nitrates may take place.

Phosphorus. Phosphorus exists in the soil in compounds, most of which are insoluble, and it is

well that it is so, or much of it would leach away in drainage waters beyond the reach of plants. Good cultivation, lime in the soil, and a generous supply of humus encourages the formation of phosphates that are soluble in water, and hence available food for plants.

Potassium. Potassium is found in the soil to a great extent in compounds that are not useful as plant food, but the presence of lime and humus, together with good tillage, effects such changes as render it readily suitable and available.

Lime or Calcium. Lime exists in the soil as calcium. It must be there, as we have seen, in order to obtain the best results. It is a plant food itself; by assisting in chemical changes it helps to render available other plant foods; it tends to sweeten sour soils and it changes the physical properties of the soil by making clay less sticky. In most prairie soils there is a sufficient supply of lime. Other ash materials enter into the structure of plants, but the farmer does not have to concern himself about them, so we shall not study them here. From what has been said about the chemical properties of soil, we see that it is of great importance to put in practice good methods of tillage so as to render the soil in good physical condition; to provide a good store of moisture; and to have the soil supplied with a large amount of humus in order

that the necessary compounds may be readily available for the use of the plant.

EXERCISES

1. What do you understand by the terms element and compound?
2. Name some of the more important elements that enter into the make-up of a plant.
3. What elements come from the soil and what from the air?
4. Do plants make direct use of elements or of compounds?
5. What must be one property of all foods that are obtained by the plant from the soil?
6. Give reasons for keeping a good supply of humus in the soil.

VIII. THE SOIL—A HOME FOR BACTERIA

You have already learned about bacteria, so it will be necessary in this lesson only to draw your attention to some of those that work in the soil for the benefit of the farmer's crops, and of course for the farmer and his family, and for the whole family of mankind.

These minute bacteria that inhabit the soil must live, and in their efforts to do this in the best way, they manufacture and throw off products that are either helpful or harmful to the growth of plants. One kind of bacteria makes it possible for plants to live and thrive on the products of their handiwork, while others, just as active, render the lives of our

economic plants most hazardous. Now, since this is true, it should be our aim to know something about the part they play in our system of agriculture, and be able, if possible, to make the conditions most congenial for the good kinds, and as uncongenial for those that endanger the lives of the crops.

Bacteria live and multiply very fast in the first three or four inches of the soil, and may live even deeper, as we shall see later on. As a sample of a helpful species, we shall study what are called the "*niter*" bacteria. These are instrumental in forming nitrates from the humus of the soil, and we have learned that nitrates are absolutely necessary in order to produce a good yield of high quality grain. Niter bacteria are very particular as to the conditions under which they will work. They refuse to do anything when the ground is colder than 41° F. They work the hardest at 98° F. and slacken up again and come to almost a standstill when it gets to 113° F. You see they are very particular about heat and cold. Not only are they particular in this matter, but also as to moisture. They will not work in a dry soil, nor in a soil that is over wet. They cease work when they cannot get a sufficient supply of oxygen, and we should do the same as they in this respect.

But strange as it may seem, in the very same soil there are a species of bacteria that will work

their hardest under almost opposite conditions. When the soil is cold, wet and poorly supplied with oxygen, these bacteria will pull nitrates to pieces, feed on the oxygen and let the nitrogen go free. These are destructive, and are called denitrifying bacteria.

The farmer should see to it that the niter bacteria are supplied with humus and surrounded with the most suitable environments in which to do their best work in his behalf; namely, to tear down humus and convert the nitrogen into nitrates for plant food. In so doing he will render it impossible for the harmful kinds to operate.

Other Helpful Soil Bacteria. Other helpful soil bacteria are those that live upon the roots of alfalfa, sweet clover, red and white clover, peas, beans, soya beans, vetches and others, all belonging to a family of plants called the *Legumes*. These plants bear their fruit in a pod. Isn't it a wonderful provision? And wasn't it a wonderful thing that *science* did for agriculture when it discovered that on the roots of these plants millions of little germs live that have the power of taking the free nitrogen out of the air and storing it up for the use of the plants upon whose roots they exist? Now, it is a fact that these bacteria have this power. They live on the roots in little bundles called *tubercles*, suck the sap out of the

roots, and in return gather nitrogen from the air and store it up for their host. Bacteria that live in this relation to other plants are said to be *symbiotic*. These nitrogen-gathering bacteria are of different kinds. There are many of them, almost as many as there are different kinds of legumes. The alfalfa and sweet clover plants are hosts for the same kind of bacteria, but this, so far, is the only case known where the same nitrogen-gathering bacteria live on the roots of two different species of legumes.

We should be anxious to get alfalfa or clover to grow in our fields, since they invite and provide for the welfare of such useful, industrious guests. Sometimes it happens that these little workers have not found their way to some of our fields. If they haven't, then the legumes, such as alfalfa and clover, will not do well. The seed will sprout, but only a yellow, sickly plant will result. In such cases it is better to bring the soil from some old field where we know the bacteria live in great numbers. From a hundred to two hundred pounds of this bacteria infected soil will sow an acre and will insure the best kind of results with alfalfa and clover. We need these crops growing in our fields if our system of agriculture is going to be *permanent*. If we are able to grow alfalfa and clover successfully, it will render our land much more valuable than

it is now. It will mean that much larger crops of wheat and other products can be raised on the fields where these leguminous crops have been because of the nitrogen gathered and stored for their use.

EXERCISES

1. Tell some things that certain bacteria do.
 2. What are niter bacteria?
 3. Outline the effect of temperature upon the work of niter bacteria.
 4. In what way are bacteria helpful to farmers?
 5. Give some examples of bacteria that are harmful: first, to crops; second, to the welfare of man.
 6. Get samples of legumes with tubercles on the roots.
 7. Have drawings made to illustrate tubercles on the roots of legumes.
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IX. THE SOIL—TEMPERATURE AND AERATION

Seeds germinate only when they are warm enough. When the temperature is from 41° to 55° F. germination is very slow. It is strongest and best at from 70° to 85° F., and at 100° or above, the temperature is so hot that it cooks the seed.

Now, since the soil is the natural environment for the germination of seeds, it follows that there is a best temperature for it, and that anything the farmer can do to provide a suitable temperature in the soil will be to his own advantage in

the stronger germination and growth of his crops.

The soil gets a large amount of its heat directly from the sun, some indirectly, and a little from chemical action that takes place in the soil itself.

The rays of the sun warm the soil. When a field or farm inclines towards the south or south-east or south-west, it is warmer than it would be if it sloped in other directions, because the rays of the sun strike it more directly. It is on this account that crops are earlier on such exposures. It is on account of this fact, too, that orchards are planted on northern exposures. The ground remains cold later, blossoming is retarded, and the danger of injury to buds and blossoms from late frosts is avoided.

Color. Black soil is warmer than white soil, and the darker shades than the lighter ones, other things being equal. Put some seeds in two pots of the same kind of soil. Cover the surface of one pot with soot and the other with chalk. Water both alike and set them in the window. Observe which one has more rapid germination. It sometimes happens that black soils are colder than light-colored soils, but this is due to other conditions than color. Since humus renders soil black, and since black soils are warm, it should be our aim to keep the soil well supplied with humus.

Moisture. Dry soils are warmer than wet soils. This is one reason why sandy soils are warmer than clays. The sand holds much less water and consequently warms quicker, but clay when once warmed retains its heat longer. Well-drained soils have an advantage in this respect over *water-logged* soils.

A warm rain that can sink quickly into the soil carries with it warmth, and a cold rain has the opposite effect. Warm and cold winds act in a similar manner upon the soil.

Compact and Loose Soils. Compact soils warm up much faster in the spring than do loose, stirred soils. A loose soil *mulch* prevents the cold from coming out and the heat from going in, and so keeps the soil cooler. We shall have to study the question of mulches pretty carefully on account of their relation to both warmth and moisture.

Chemical Effects. When vegetable or animal matter decays in the soil there is always heat given off, and this has a warming effect upon the soil. The rotting of the prairie sod is accompanied by this action. Before chemical action can take place in the soil there must be heat, moisture and air. You see how important it is that weeds and rubbish of all kinds be ploughed under before the summer rains are over in order to have them decay before next season's seeds are sown.

Aeration. This is the process of airing the soil. We air the milk in order to free it from animal flavors. We air or ventilate our houses, school-rooms and stables that they may contain a pure and wholesome supply of air for the purpose of breathing. Now it is absolutely necessary for the sake of the life and growth of the plant, that the soil be well aired or ventilated. The roots require oxygen in order to carry on their important functions. If niter bacteria are to live and multiply as we wish them to do, they must have a good supply of oxygen. If this element is not supplied, and if, on the contrary, it is excluded from the soil, then the destructive or denitrifying germs will operate to the detriment of the farmer's interests. The free circulation of pure air drives out gases and impurities that collect in the soil and interfere with the best plant growth.

The soil breathes, as it were, and we should make the conditions most suitable for it to do this. Good tillage is the means at our disposal. In some places it is necessary to underdrain the soil in order to produce the best results in this respect. Of course, if air circulates too freely in the soil, there is a danger of too great drying and a consequent loss of crops through drouth. Farmers must study their own soils and their own work and do the things that will bring the



A WELL-MADE SUMMER FALLOW, PLOUGHED EARLY IN JUNE AND KEPT
BLACK DURING GROWING SEASON.



A CLOVER FIELD IN THE PRAIRIE PROVINCES.

best and most lasting results. Remember that a good soil in the best condition contains both air and water at the same time, as we shall see in a future study.

EXERCISES

1. With a good thermometer take the temperature of the soil at different depths—one inch, two inches, three inches—on Monday and Thursday of each week from the opening of spring until harvest.
2. Find out if you can, by boring with an inch and a half auger, how deep the frost goes into the soil and how long it is thawing out of an exposed field.
3. What effect has temperature upon seed germination?
4. What is the best temperature for germination?
5. What is the effect of color, moisture and compactness upon soil temperature?
6. What effect has the rotting of sod upon soil temperature?
7. What are the ill effects that would be noticed if air is not allowed to enter the soil?

X. SOIL MOISTURE—ITS USES AND KINDS

The question of soil moisture is one of prime importance to the agriculture of the Prairie Provinces. In fact, it is one that can scarcely be over-estimated, so far-reaching is it in its effects upon the crop-producing powers of the soil. Soil moisture has so many duties to perform that we may well review the most important just here.

1. The plant gets practically all of its water from the soil. The weight of most growing

plants consists of from 65 to 95 per cent. of water. Some of our vegetables, such as potatoes, carrots, turnips and beets, contain from 80 to 91 per cent. of water. Prof. King of Wisconsin has, by careful investigation, found that on an average our farm crops require more than 400 tons of water in order to mature one ton of dry matter. In other words, for every ton of dry matter built up by the oat plant, over 500 tons of water were taken in by the roots, passed up through the stem and *transpired* by the leaves. The wheat crop required over 400 tons to do a similar work, and a 400 bushel to the acre potato crop required over 1,300 tons of moisture for the plants alone. Besides this much water passed away from the soil through evaporation. It is important that we bear in mind always that our crops require moisture for seed germination, for growth and for bringing themselves to maturity, and that this moisture must be served to them from the soil; especially is this true of our grains and root crops.

2. All the important changes taking place in the soil, so far as plant food is concerned, must do so with the aid of moisture. Niter bacteria are active only when supplied with humus, oxygen, warmth and moisture. Chemical decomposition of soil particles is possible only through the agency of moisture. Plant foods, such as nitrates, phos-

phates and others, must be dissolved by water before they can enter the roots for the use of the plant.

3. Water fills the cells of the plant and keeps it *turgid*. When there is an insufficient supply of water the plant wilts.

4. Water carries the food that is manufactured in the leaves to all parts of the plant to build up tissue—even to the farthest tips of roots and branches.

5. Then we have another use for the water of the soil, and that is for drinking purposes for both man and the domestic animals. Before locating a home one of the first questions we ask is, "Can we get good drinking water?"

Kinds of Soil Moisture. Water is received by the soil in the form of rain and snow from the clouds. Some soils are of such a nature that all of the rain falling on them sinks down and disappears. Other soils are of a close nature and can receive only small quantities of water at a time. They run over and the water stands on the surface or runs away through surface-ditches and streams. Water is said to be of three kinds, according to the manner in which it exists in the soil—free, capillary and hygroscopic.

When water falls on the soil and sinks down through the pores among the soil particles, it is said to *percolate*. Water that fills all the pore

spaces is called *free water*. Water that percolates is free water. If we dig deep enough into the soil we come to free water. Sometimes it is near and sometimes even hundreds of feet below the surface of the soil. When free water exists within eighteen inches of the surface of the ground for any length of time, it has a damaging effect upon crops. You have seen crops killed out where free water has lain on the surface for a few hours. The reason for this is that the air is driven out of the soil and the roots suffocate for want of oxygen. Free water is not used by the roots of plants.

Capillary Moisture. Capillary moisture exists as thin films about the soil particles. It is held by a force called *surface tension*, and by the same force is drawn from one part of the soil to another. This force acts most easily and most quickly in moist soil. The greatest attraction is from zones of more moisture to zones of less moisture. Water travelling in this way from soil particle to soil particle through the pores, as in fine hair-like tubes, is called *capillary* moisture and the process is called *capillarity*. Water may travel by capillarity in any direction—up or down, to the right or left, or in a slanting direction. It is by this capillary attraction or pull that moisture is brought from the lower depths of the soil to the surface to supply the needs of growing plants.

We shall study in another lesson how to make the conditions most suitable for providing deep-rooted plants with a continual supply of moisture through the season of growth and maturity.

Hygroscopic Moisture. This is moisture that is still held after the soil has been thoroughly air-dried. It may be driven off by intense heat. It is held so tightly by the soil particles that it is of little use to plants. In fact, plants die long before they can secure any refreshment from hygroscopic moisture.

EXERCISES

1. How many inches of water falls on your soil during the year in the form of rain and snow? Ten inches of snow is equal to one of rain.
2. How many inches fall during May, June and July?
3. When water stands one inch deep on an acre surface, it is called an acre inch. How many tons in an acre inch of water?
4. Of what use is water to agriculture?
5. Take a quart plant jar full of dry soil. Weigh the jar and then weigh it again when full of soil. Set it in a basin. Pour water over the soil until it runs out of the holes in the bottom into the basin. Wait a while and observe what happens. Then pour water in again until it runs out. Observe again. Does the same thing happen as it did before? Place something under the jar so that water can drip out into the basin. When dripping has ceased weigh jar and contents. Calculate the amount of water the jar contains. Explain what is meant by free water and capillary water.
6. Take two lamp chimneys. Tie cheese cloth or gauze over the lower ends. Fill one three-quarters full of coarse soil, like sand or gravel. Fill the other three-quarters full of

fine loamy soil well compacted by shaking down. Place a plump kernel of wheat one-half inch deep in each. Place both chimneys in a pan with one inch depth of water in it. If the water in the pan disappears put more in. Observe what takes place in the soil within the chimneys. Which kernel sprouts first? Record your observations and make comments.

7. Take a lump of dry soil and place it in a saucer having a little water in the bottom. Observe what takes place.

8. What do you call the process that carries oil from the lamp bowl to the burner?

XI. SOIL MOISTURE—ITS MOVEMENTS AND HOW IT IS LOST

The movements of water in the soil are brought about by three different agents: gravity, capillarity and evaporation. *Gravity* causes water to percolate or fall down among the soil particles until it has distributed itself as capillary moisture or until it finds the ground water, or water table, as it is sometimes called. Water moves about in the soil, being pulled up or down to right or left from wetter to drier and to more compact soils by capillarity. In all good soils there is nearly all the time a circulation of more or less air. When warm air circulates in the lower depths of the soil, it evaporates moisture from the particles and deposits it in soil zones where it is cool enough to condense the water vapor. These are

the ways in which water moves in the soil. Now, how may it get away from the soil and be lost entirely so far as plants are concerned?

Evaporation. You have learned in another lesson what is meant by evaporation. You have seen the water evaporating as steam from a kettle on the stove. You have noticed it disappear from the sloughs during the heat of summer. Now, from the surface of the soil during the spring and summer months, large quantities of water are being evaporated every day, except, of course, when it is raining or very damp. Professor King of Wisconsin found by investigation that an acre of ground left unploughed one week later in the spring than an acre of similar soil, lost about 9.5 lbs. more of water per surface foot than the acre that was ploughed first. This means about 200 tons more per acre, or half enough to mature a ton of dry matter in the wheat crop. This amount of water, if spread out over an acre, would measure about two inches in depth. As the water evaporates from the surface, other water in turn is brought up by capillarity from the lower depths of the soil only to meet a similar fate, and so the soil is dried completely out. When the soil is left coarse and open, dry air circulates freely, and, coming in contact with moist soil grains, carries off large amounts of water from the inner surface of the soil.

Percolation. Coarse, gravelly or sandy soil allows the water to flow down through it very quickly and lose itself beyond the root zone of the growing crops. The water in this case is not the only loss, for it takes with it plant food in solution that is carried away, probably never to be returned to this particular soil.

Surface Drainage, or Washing. Rain falls on some soils that are so impervious to water that before much is absorbed great quantities have run away to lower levels to make ponds, carrying with it much of the finer, richer soil from the surface of the field.

Weeds. We have already found out that economic plants take from the soil large quantities of water. Weeds are even more extravagant in this respect. The common mustard plant requires more than 900 tons of water to pass in through its roots and out through its leaves to mature one ton of dry matter. Wild oats, Russian thistles, wild buckwheat, French weed, sow thistles, and others all require large amounts of water in order to thrive as they do in our fields. You can readily see that very large quantities are in this way lost from the soil.

EXERCISES

1. Take a half dozen long necked bottles and break the bottoms off. This may be done by filing a groove parallel with the bottom and then holding a red-hot piece of iron such as a poker in the groove. When the glass begins to

crack, circle the bottle with hot iron and the crack will follow. Fill the bottles to the neck with different kinds of soil. Tie a piece of thin muslin or cheese cloth over the bottoms. Pour water in at the top of two until it runs out at the bottom. Place two others in a pan of water.

What force moves the water downward in the first two bottles? What force moves the water upward in the second two?

Take two of the bottles whose soil is filled with water, and pass warm dry air through them. What happens to the soil? Where does the water go?

2. Which kind of soil allowed the water to run through it quickest?

3. Which kind of soil allowed the water to rise quickest and highest in the first hour?

4. Why are potatoes smaller in a hill where large weeds are left growing than in hills where there are no weeds?

5. Take two tomato or apple cans and fill both with an equal weight of dry garden soil. Shake well so as to settle the soil. Weigh into each an equal amount of water. Cover one with one-half inch of dry sand which has been weighed. Pack the surface of the other can with the hand and leave both exposed in a window. Weigh in seven days and account for difference in weight, taking into account the sand added to can No. 1.

XII. SOIL MOISTURE — HOW TO CATCH AND HOLD IT

Some soils are better for catching and storing water than others. Sandy and gravelly soils are very poor reservoirs indeed. Water runs out of them very quickly, and any that may cling to the particles is quickly lost through evaporation

into the air. Clay makes a much better reservoir. The particles are finer, there is more friction as the water is percolating, and there is a much greater surface to which the water may attach itself and remain as capillary moisture. Sometimes clay is too fine, and in such cases the water runs off the surface before the soil has had time to catch very much. Soils of this kind are hard to work. A cubic foot of sand when completely filled will hold about twenty pounds, while a cubic foot of clay will hold over thirty pounds of water. Humus will hold over fifty per cent. of its own weight of water. The best soil for holding water is a nice loam with a large amount of humus in it. If a farmer can have a choice in selecting his farm, he should by all means endeavor to secure soil that will make a good reservoir, that is, one that will hold a large amount of moisture. The farmer himself can help his soil very much in this respect. When soils are too compact he can loosen them up with the plough, choosing such a shape as will pulverize best. In stiff clay soil where there is but little surface soil, he can use what is called a subsoil plough. This will loosen up the furrow soil and make a deeper reservoir. Then the surface soil can be turned back. He can compact sandy soils with a packer or roller and thus render them more retentive. And better still, he can add humus and very

materially increase the water-holding capacity of sandy and loamy soils. This is done by applying well rotted manure, by ploughing under green crops, by growing clover and alfalfa, the roots of which enrich the soil in humus. You can see from what has been said that the farmer must be a student of his own soil or soils, as there is likely to be many kinds on his farm, and then treat them so as to make them most effective water holders.

How to Conserve the Moisture. The question now arises, how can we retain this moisture against evaporation? It has been found that where a layer of straw, sawdust, fine dry soil grains three inches deep, or a blanket, has been placed over wet soil, the moisture is conserved or held in. If the surface is left bare the water escapes and is evaporated at the rate, oftentimes, of 300 tons or more per week, according to the amount of sunshine and wind. Now the best plan yet found for the farmer to conserve moisture in a large field is to pack the soil to prevent too free circulation of air, provided it requires this treatment, and to make a mulch or dry soil blanket with the harrows. This mulch is most effective and produces the best results when about three inches deep. The mulch should be maintained as long as possible where the object is to keep the moisture in the soil for the use of crops.

Loss from Weeds. Weeds have been termed the "poor farmer's friend." The reason for this is that they make the most careless, indifferent farmer cultivate to get rid of them. Of course, this is what all should do. If weeds are killed by timely surface cultivation, two useful purposes are served—the loss of moisture through transpiration, and evaporation are prevented.

EXERCISES

1. What are the sources of soil moisture?
2. At what time of year do our rains come?
3. How many inches of rain fall in your school-yard during the year?
4. About what percentage of the year's rain falls in your locality while the crop is growing?
5. What kind of soil is best to hold moisture?
6. How can the agriculturist increase the water-holding capacity of his soil?
7. Suggest practical ways of rendering sandy soil, loamy soil, and clay soil more retentive of moisture.
8. What effect upon the conservation of moisture has the cultivation necessary for killing weeds?

XIII. THE SOIL—HOW TO MANAGE IT

We are interested in the soil because it is the home of the plant. It is the source of a very great deal of our wealth. The best, most productive soil is that which contains plant food in abundance; has a sufficient supply of water; is in such a condition that water and air can

move about freely among the particles; has not an excessive amount of alkali; is rich in humus; and, withal, is infested with the bacteria whose life work is to form plant food from the ingredients of the soil and air. We have learned of the different kinds of soil and some of the properties of each kind. Now, farming is a business, and the farmer, to be successful, must be a student of his soil in order that he may know just how to manage it so as to get from it the very best returns and leave it in a better condition than when he first occupied it. You know how careful we have to be with the colt from the time he is little until he has been trained to work, and how careful we must be then as to his feeding, care and management until grown up, in order that he may be healthy and able to work six days a week. Our cows, too, must get the best of care in every way if we are to get the best returns from them, either in the way of growth or of milk and cream. Just so with our soil. It will not do to have a good crop on one part of a field while there is only half a crop on the rest of it. It is a condition of this kind that reduces our average yields and makes our returns so small that we can scarcely make ends meet. Every farmer must study his own soil and manage it so as to bring it up to its maximum production and then keep it there.

Tillage. *Tillage* means the working of the soil with the different implements, such as the plough, cultivator and harrow. There are four principal reasons for tilling the soil. The first is to make a seed-bed in which to sow the seed; the second, to put the soil in such physical condition—*tilth*—as to make it the best possible home for the plant, as to fertility, moisture, warmth and air; the third, to make it possible for the root-hairs to travel among the particles in search of food; and the fourth is to kill weeds and conserve moisture.

The plough is the most important implement of tillage. It has been used in one form or another for centuries. First, it was only a sharpened stick, and from that it has developed through the different forms and shapes until we have to-day almost a perfect implement in the mould-board plough. The work it has to do is to cut, lift, turn and break up the furrow slice. Of course, the breaker or sod plough is not intended to pulverize the furrow, but is expected rather to cut, lift and turn the furrow over flat. When once the breaking is done, it is expected to pulverize the furrow slice, and this accounts for the steeper mould-board of the stubble plough. Of all the work in connection with tillage, ploughing is perhaps the most important. It must be done at the right time, with the right type of plough

and at the right depth. When farmers are careless about this most important piece of farm work, they, as a result, have to pay for their carelessness by reaping poor crops.

Of all the soils, clay and gumbo are the most difficult to plough. They are composed of such fine particles, and are so sticky when wet and so hard when dry, that if they are worked in either of these conditions, they are spoiled for a long time. If clay is ploughed wet, the granules break up into grains and they run together, and the clay *puddles*. This is the condition in which clay is rendered to make pottery. When clay puddles, it lets neither air nor water through it. In this state seed will not germinate, nor will plants grow. Sometimes farmers are in such a hurry that they spoil a field of clay by ploughing when it is too wet. You can easily tell when it is in this condition, for the furrow slice will shine and glisten when it is turned over. In the wind and sun it soon bakes and gets as hard as brick. The only way to recover its former texture is to leave it to the action of moisture and frost. It may take a long time, but the farmer has himself to blame for the loss. Clay when it is fit to plough will crumble into granules and should not be ploughed until it will do this.

Sand is better ploughed when a little wet and in this condition cannot be injured with the plough.

Loamy soils can be ploughed on the damp side, but as to how damp will depend upon the proportion of clay they contain.

Depth of Ploughing. The plough can turn a furrow from about two inches to twelve inches in depth. As to how deep you should plough will depend upon what you wish to accomplish. Here in the Prairie Provinces, we are much interested in catching and holding a large amount of moisture. Our soils have been forming for centuries with the action of water and wind. In many parts they have become compact. The fine particles need loosening. One good deep ploughing would help these soils and would not require to be done again for years. After ploughing deep, the soil should be packed and made as firm as possible with a packer or roller. The depth to plough even in this case will depend upon the amount of good soil there is on the surface. If it is very shallow, then you should plough only a few inches, say three or four or five at most, for if you go deeper you will turn the good soil too far below, and you will have on the surface only a hard, lifeless earth in which plants cannot thrive. Soils of this kind are usually clay or sand. If clay, then it would be better to plough a furrow, say four inches deep, and then follow along and loosen up the bottom of the furrow with what is called a *sub-soiler*. This



HOW A GOOD PLOUGHMAN STRIKES OUT HIS LAND.
 Every part of the soil is cut and inverted and stubble and weeds covered.



A GOOD PLOUGHMAN FINISHING HIS LAND.
 Notice the even finish, as well as the careful way he has pulverized the soil and covered all rubbish.

implement does not turn a furrow, but simply loosens or stirs the bottom and makes the reservoir deeper for holding water. The air is able to circulate more freely to a greater depth, and this has a good effect upon the subsoil. On account of the presence of both air and moisture, the roots of plants penetrate farther down into the subsoil and through their action leave it in a better physical condition.

Deep ploughing is done, too, for the purpose of working humus down to a greater depth, and so increasing the size of the root zone and increasing the water-holding capacity of the soil. It must be borne in mind that the greater the water-holding capacity, the colder is the soil, and the looser the soil the colder it is as compared with a more compact soil in the early spring. So it follows that when a soil has been loosened with the plough in order to give it a better texture, it should be immediately packed in order to prevent too free circulation of air, to render the movement of water upward easier, and to increase its warmth.

Ploughs are of two kinds, the common mould-board and the disk plough. Some soils, such as very fine clay and gumbo, are so sticky that the mould-board plough will not clean, and very untidy work and poor tilth is the result. In this case the disk plough does better work. The disk

has a better pulverizing effect when dry or wet clay has to be ploughed, but in all other cases the mould-board plough is to be preferred, being lighter in draft and doing more efficient work, all things considered.

The Harrow. The harrow is of three different kinds: the disk, the drag or smoothing harrow, and the spring-tooth. The disk lifts, turns and pulverizes, and also has the effect of compacting the lower soil in the sole of the furrow, especially when run lengthwise of the furrow. The small fourteen- or sixteen-inch disks do more effective pulverizing than the larger disks when set at the same angle and driven at the same speed. It is better usually to have the disks throw in, rather than out, for the out-throw keeps heaping up the soil at the outside of the field, which is undesirable. Unless the disk harrow is lapped, it leaves an undesirable ridge at every round.

The drag, or smoothing harrow, has spike teeth and is sometimes so constructed that the teeth may be tilted forward or back by means of levers. This type of harrow pulverizes the surface, tends to break down clods and smoothes the surface. On account of the shape of the teeth, the drag harrow packs the sub-surface soil and establishes capillarity, at the same time leaving a three-inch mulch on the surface to prevent evaporation. The spring-tooth harrow lifts, loosens and pul-

verizes the soil. It can, however, loosen only as deep as the furrow has been turned. Cultivators, like harrows, follow the plough and are used to put the soil in better tilth. They are sometimes used on stubble instead of the plough.

All of these implements are effective in killing weeds. The harrow kills weeds most effectually of all, provided it is used at the right time, that is, when the weeds are in the milk, just nicely sprouted and showing above the ground. If more than a week old it will take a disk, a duckfoot cultivator or a plough to kill them.

Packers. Packers belong to the tillage implements, too, for they assist in improving the physical properties of soil and affect its tilth, texture, compactness, warmth, and air and water-holding powers. Packers are of three types: There is the common roller. It breaks down clods, evens the surface, and leaves the soil compact and smooth. The harrow should follow immediately after the roller in order to form a mulch and so prevent excessive evaporation. The corrugated roller or packer breaks down clods, compacts the soil and leaves the surface mulched. The V-shaped wheel packer compacts the sub-surface soil and leaves it in little furrows and ridges that serve as mulches and at the same time prevent blowing. This is suited to different soils and to somewhat different purposes.

A planker is an implement made by bolting three to six 2 by 12-inch planks together in clap-board fashion, each overlapping the other about three inches. This is drawn over the field for the purpose of breaking clods and smoothing the surface.

Other implements may be devised and used for the same purpose as those already described. The farmer before buying implements in a wholesale manner, should study his soil in order to find out its nature and the treatment it should have, and then get the implements that will effect his purpose.

EXERCISES

1. What should be the object of the farmer as regards the soil he has under his control?
2. Look up the meaning of the word *agriculture* and see if all the farmers you know are doing what is implied in the word.
3. Explain what is meant by tillage and tilth. Get samples of soil to demonstrate good and poor tilth.
4. Discuss and explain the work that is done by the different implements of tillage, such as the plough, harrow, cultivator, packer, and hoe.
5. What is meant by the following terms : clods, puddling, hardpan, blowing?

XIV. THE SOIL—HOW TO MANAGE IT (continued)

Drainage. Here and there in the prairie provinces we find stretches of land that contain too much free water to permit the growing of our best crops,

and in some places so much even that the land cannot be tilled at all. Now, the taking away of this free water is called drainage. Large areas of land that were of no practical value because of the excessive amounts of free water they contained, have been made valuable by drainage. The Red River valley, made up of the richest kind of soil, requires drainage in many parts to make it produce the maximum. In this valley, in the State of Minnesota, a tract of land comprising 250,000 acres has been made fertile by the running of a large ditch through it for drainage purposes. In Manitoba, too, large areas of this same valley are being rendered fit for crop production by the digging of deep open ditches for the purpose of taking off the superfluous free water. As time goes on, and as land becomes more valuable, more and more will be reclaimed by this means.

Drainage is accomplished in different ways. In some places the land is diked and the water pumped out by means of windmills and engines. This is done in Holland and on a smaller scale in other countries. The other and more common practice is by ditches which are of two kinds—the open and the closed ditch. The open ditch may be a shallow surface ditch made with a plough, or it may be deep and wide, made by means of machines for the purpose. The closed

ditch is made by first digging a trench and then making a passage in the bottom for water, by means of stones, brush or tile covered with earth. The open ditch is usually a nuisance in a field, as it interferes with tillage and harvesting operations. It is expensive to maintain, as it soon fills up. It is hard on machinery and causes losses in soil fertility, due to washing away of the finer portions of soil. The main open ditch is usually run through the lowest portion of the area to be drained, and the feeders are run along crosswise of the base of the slope to catch the surface and seepage water. Sometimes only surface ditches are thrown out with a shovel or plough in order to surface-drain a low spot in a field. Open ditches should have their sides grassed, if possible, to prevent their washing and also to prevent the growth of noxious weeds. They should be dug as nearly straight as possible in order to keep up a continuous flow. Abrupt turns interfere with the flow of the water and cause overflowing.

Underdrainage. By underdrainage we mean the taking away of the water from below. This is accomplished by means of the closed drains spoken of above. But it is an expensive undertaking to try to take away the free water from below, for ditches have to be dug and then passages carefully made in the bottom to carry the water away to the outlet; and we naturally ask, what can we

expect in return for this outlay ? The answer in brief is, "surer and better crops."

Underdrains take away the free water and thus leave a larger pore space and hence a much larger feeding ground for the roots.

Deeper rooting is encouraged and insurance against loss through drouth is accomplished.

The amount of capillary water upon which the roots may draw is much increased.

Evaporation is prevented and the soil made warmer on this account.

Poisons in the soil are leached away and carried off in the underdrains. Alkalies in the soil are thus removed by underdraining.

Better aeration of the soil is brought about.

The best drains are made of tile. These tiles are made of burnt clay like brick. They are round and range from two inches in diameter up to almost any size, according to the amount of water to be carried off by them. Those used for underdrainage are one foot in length. They are laid end to end in as nearly a straight line as possible, and should have a gradual and uniform slope to the outlet. One inch fall in 100 feet is considered sufficient. If the line of tile should sag in any part, the water runs slower, sediment is deposited and the drain gradually fills and causes trouble. It is best to have the work carefully and well done at

first so as to avoid future trouble and loss. The main drain is run through the lowest part of the field and then the laterals, as the feeders are called, drain other low areas. They are laid about three feet deep in the ground. They should be below the root zone so as not to fill up with roots. The laterals should enter the main at an acute angle so as not to interfere with the flow of water. The drains may be from 25 to 100 feet apart, according to the kind of soil to be drained. Clay requires closer drains than sandy soils.

When clay soil is underdrained it causes it to become more porous, and all the benefits of aeration, root penetration and elaboration of plant food follow. In this northern country where the frost penetrates the ground so deep and remains so late in the spring, tile or under-drainage presents problems that have yet to be solved by government investigation at the agricultural colleges and experiment stations. Little work of a definite character has yet been done in this respect in the prairie provinces. The tiles being surrounded by frozen earth might freeze full of water and thus prevent the taking away of water from sloughs at the time when most needed, and at the same time would be destroyed by the expansion due to freezing.

Irrigation. There are large areas of soil, rich in plant foods, that require more water than

they get from rains to enable them to produce paying crops. Much of this land on the North American continent lies not far east of the Rocky Mountains. Water is caught in ponds or lakes and is then led by means of ditches to these lower lands and let run over them through sluice gates. You have seen just such practice as this in your own garden when the hose or the watering can was used. You have noticed the grass and the flowers and vegetables grow much faster for such treatment. This way of applying water is called irrigation. On the large areas this method has made it possible to grow large crops of wheat, alfalfa, peas, oats, rice, potatoes and other vegetables, grass and fruit. It has turned what were once deserts into regions of splendid homes. It has made crop raising sure and has made agriculture a permanent occupation, so long as water can be obtained for flooding these areas. In Western Canada we have irrigated lands in southern Alberta and in British Columbia. Other areas will no doubt be brought under similar systems, and much land now thought useless will be made to produce in abundance. Where irrigation water is available it is possible to wash the alkali out of soil and carry it down out of reach of plant roots, or off entirely through underdrains.

EXERCISES

1. What do you understand by the term drainage?
 2. When does soil require drainage?
 3. Take two tomato cans. Punch holes in the bottom of one and leave the other intact. Fill both with soil and shake well. Then fill with water until the soil is saturated. Plant five wheat grains in each, two inches deep, and watch results. Water both cans alike.
 4. Is there any part of your farm or locality that requires drainage?
 5. What is meant by surface drainage? Underdrainage?
 6. What are the necessary precautions to be taken in laying underdrains?
 7. What are the objections to surface drains?
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XV. THE SOIL—HOW TO MANAGE IT (*continued*).

Impoverishment. In previous lessons we have learned that the dry matter of plants contains about five per cent. of ash or mineral matter, and that this comes directly from the soil through the roots to the plant. We have learned also that plants gather their supply of nitrogen from the soil in the same way. Plants cannot thrive unless they have a sufficient supply of both ash and nitrogen in their food supply. The important elements are nitrogen, phosphorus, potash, iron, lime, magnesium and sulphur; of these the farmer need concern himself only regarding the supply of nitrogen, phosphorus, potash and lime. All the others are found in sufficient quantities to

last for ages. Now, it is the presence of these, together with moisture, that constitutes a fertile soil. Some soils are much more fertile than others, depending, of course, upon the materials of which the soil is composed, and all more or less affected by its physical condition.

When a farmer grows a crop of wheat of, say, twenty bushels to the acre, he removes from the soil in grain and straw, 34.68 pounds of nitrogen, 14.4 pounds of phosphoric acid and 27.6 pounds of potash. It is easy for us to see that if continuous cropping goes on, sooner or later the amount of these foods in the surface soil must be depleted to such an extent that profitable crops cannot be secured. Even if the soil is depleted of only one of these essential foods, the yield will be seriously interfered with. Plants cannot get on without potash any more than they can get on without nitrogen. An overdose of one will not make up for an insufficient supply of one of the others. It is quite clear to us, then, that continuous cropping of grain from the soil tends to impoverish the soil. In England, at the Rothamsted station, it has been found that paying crops of wheat can be grown for more than twenty years without putting anything back into the soil. Then the yield dwindles down to between 12 and 13 bushels per acre, and remains quite constantly at this.

Every time a piece of land is summer fallowed, the humus is burned out of the soil during the process. When a soil is depleted of its humus in this way, it is robbed of its fertility, for the humus is the great source of soil nitrogen. It adds also very much to the water-holding capacity. Humus is called the life of the soil.

Maintaining Fertility. Much of our soil is very fertile. So far as the mineral constituents are concerned, it would take two or three hundred crops to exhaust these but the nitrogen is more easily depleted on account of our wasteful practices. The method usually adopted for keeping up the supply of available ash materials is good tillage. This is simply rendering more plant food available for the growing crops. In some places where one or more elements are lacking, these are supplied by sowing on the soil a substance containing the needed plant food. Dried blood furnishes nitrogen and so does saltpetre. Kainite furnishes potash, and phosphatic rock and ground bone add phosphorus. These are called artificial fertilizers. While they have not yet been used in the Prairie Provinces, they are being used on land in the Mississippi valley that was at one time just as fertile as ours.

In many sections of the country much of our hay and grain crops are fed to live stock. The manure produced is put back on the land and

in a measure helps to keep up the fertility. It is especially helpful in adding vegetable matter that is finally converted into humus. Grasses that will add much root fibre are sown, and the roots add humus-forming material. Green crops, such as buckwheat, rye, vetches, peas, soy beans, and the like, are ploughed under to add vegetable matter. The greatest source of soil fertility, so far as the farmer in the Prairie Provinces is concerned, is that of alfalfa and clover. These plants, when grown on the land and cut for hay, leave the soil richer in nitrogen than it was before they were sown. They add nothing in the way of mineral matter, for all they have they get from the soil. Their roots, sometimes more than 12 feet deep, do, however, bring up ash materials from the lower depths of the soil and leave them near the surface for our shallower rooted plants. But the great gain is in the nitrogen which the bacteria, living on their roots, gather from the air and store in the soil for the use of our grain and other plants.

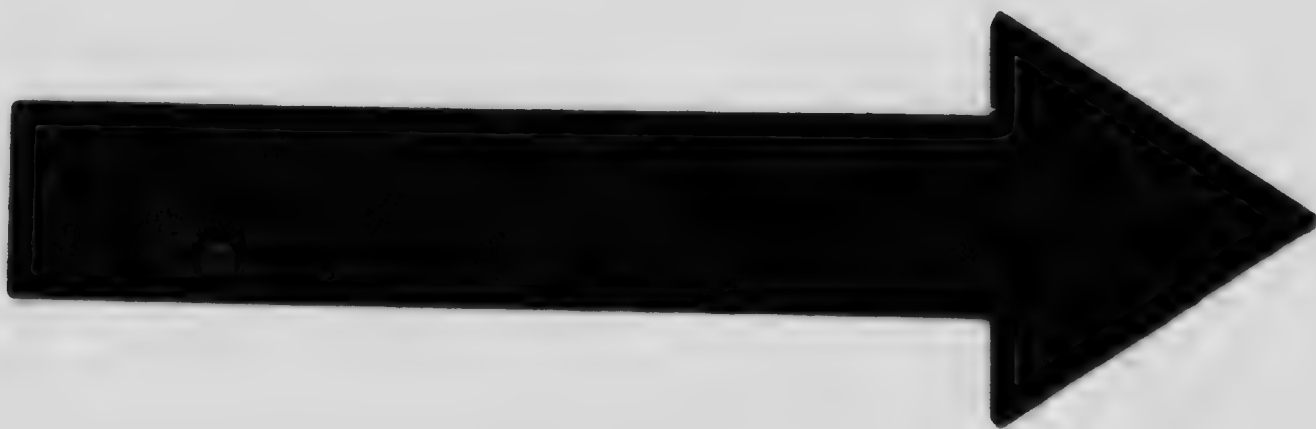
Cropping. The tendency is to grow such crops as bring us the greatest returns for the smallest capital invested, and for the least amount of work expended. This, of course, leads to what has been termed *soil mining*—"soil robbing" by some. We know we are doing it, and we know it is a good business proposition so far as we

are immediately concerned. We have already had to give up our farm, perhaps, and move to new soil, leaving the old, worn-out, run-down farm to some one who was ignorant of conditions. This is not good farming, nor is it looking to the good of those coming after us. We are, by these methods and practices, making the hardest possible way for those who are to take up the work where we leave off. The good farmer will study his business. He will grow such crops as will do the least amount of robbing and such as will maintain the original fertility of the soil. Shallow rooted plants will follow deep rooted, and nitrogen users will follow those that have stored up much nitrogen, such as the legumes already mentioned. Each kind of plant will be grown with a view to the immediate requirements of the settler and his family, the markets, the soil and the maintenance of fertility.

EXERCISES

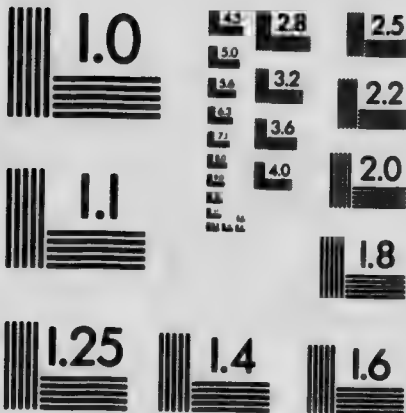
1. Name some of the more important elements of soil fertility.
2. Tell the source of each of the elements named.
3. About how many pounds of nitrogen would be removed by a thirty bushel to the acre wheat crop?
4. Name ways in which nitrogen may be restored to the soil.
5. How may phosphorus and potash be restored to soil that has been depleted of these elements?

6. What is the effect of summer fallowing upon soil fertility?
7. What is meant by "artificial fertilizer"?
8. What crops are useful in restoring and maintaining the fertility of the soil?
9. Do clovers grow in your locality?
10. What is the function of lime in the soil so far as plant growth is concerned?



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SECOND YEAR

I. CROPS

THE crops raised on the farm are of various kinds. As to which ones will be grown in any locality will depend upon many conditions, such as soil, moisture, climate, including sunshine, rainfall, length of season and frosts, proximity to local or world's markets, amount of capital at one's command, personal likings and adaptation, and the immediate needs of the settler and those dependent upon him. The kinds of crops grown will depend, too, upon what is to be done with them—whether marketed as harvested, or fed to live stock and marketed in work, meat, milk, eggs and wool.

So many uses are made of the different kinds and parts of plants that they might be classified according to the parts that are used, as follows:

Roots, such as turnips.	Seeds—wheat.
Tubers—potatoes.	Fruit—currants.
Stems—flax for fibre, straw for braid.	Flowers—peas.
Leaves—tobacco.	Stems and leaves, grasses—timothy.

The student will be able to add many names to the lists started.

There are other ways, too, in which crops might be classified, such as grasses, grains, roots, fruits, vegetables and flowers. Then there are garden, orchard and field crops that might properly call for another classification. There are shallow and deep rooted plants; nitrogen-gathering plants and those that only consume it; there are drouth-resisting plants and those that require large amounts of readily available moisture. Each class of plants forms an interesting subject of study, from the selection of the seed to the gathering and storing of the same, and the harvesting of the products for which the crop is cultivated.

It is intended to take up the study of two or three of these crops in order that a line of study may be suggested to both the teacher and the student. The same will be followed by a list of references to which we may go for further information regarding any other crop we may desire to study.

As the soil, climate, and in fact all our conditions are so admirably adapted to the growing of wheat of superior quality, we shall take this crop as a subject for crop study. A similar plan may be mapped out for oats, barley, rye, timothy, corn and other crops, and the information gathered by both teacher and pupils from all available sources.

II. WHEAT

Of the six leading cereals of the world—wheat, maize (corn), barley, oats, rye and rice—wheat occupies the premier place. It has been cultivated for over four thousand years, and nearly all traces of its original wild nature have disappeared. It is cultivated for its seed, which, after it has been prepared in different ways, is used very largely for human food. There are a great many varieties of wheat, as many as 1,000 having been tested and examined by the United States Department of Agriculture. These may be grouped in several ways, such as fall or winter and spring or summer wheat; red and white wheats; hard and soft wheats; bread and macaroni wheats; and again into hard and soft winter wheats, and so on. We have heard most about the hard red spring wheat, for which Manitoba and Saskatchewan have become world-famed, and of the hard red winter wheat which has made southern Alberta famous. Our soil, and more especially our climate, are suited to growing the best quality of bread wheats to be found anywhere in the world. Of the hard red spring wheats Red Fyfe has attained the greatest notoriety on account of its outstanding qualities as a bread-making wheat. Flour made from it is termed *strong* by the bakers, and the millers in Great

Britain are anxious to get it to mix with softer wheats imported from other countries to *blend* their flours. Other hard red spring wheats adapted to our soils and climate are Preston, Blue Stem and Stanley.* Preston and Stanley, while not up to the quality of Red Fyfe, are three to four days earlier, and on account of this they are preferred in some parts where early fall frosts are apt to catch the later variety. The outstanding hard red winter wheat is called Turkey Red. This wheat has made Kansas famous, and it is now being grown with great success, both as to quantity and quality, in southern Alberta. In several places, too, in Manitoba and Saskatchewan, fall wheat has been grown successfully, in an experimental way, during recent years, and it is believed that in the near future many sections of these provinces will be devoted to the culture of winter wheat. Durum or macaroni wheat is not grown to any extent in Canada, but is being grown in larger quantities every year in the States to the south. This wheat is very hard, but the flour

* It will be necessary for all who are interested in preserving the high standard of our wheat on the foreign market, to endeavor to grow only the best quality of grain. Otherwise the foreign buyer's estimation of our article will be lowered, and he will look to other countries for his supplies of blending wheat. Unless the best wheats can be grown it would be better for the farmer to devote his attention to the production of coarse grains and other agricultural products, rather than to be the cause of losing the confidence of the Old Country markets.

made from it is dark in color. Large quantities are shipped from the States to France and Italy, where it is used in the manufacture of macaroni. Durum wheat is well suited to dry climates. Even where the rainfall does not exceed 10 to 12 inches per annum it yields well.

Flour in Wheat. The amount of flour that can be obtained from wheat depends upon the kind as well as the quality of the grain. Soft wheats, according to the weight per bushel, make from 65 to 80 lbs. of flour out of every hundred pounds of wheat, while hard wheat, like Red Fyfe, makes from 67 to 75 lbs. of flour. The by-products are called bran, shorts, middlings and red dog flour, all used in feeding live stock. Besides these by-products there are breakfast foods, such as grits, germ meal and graham flour, for which there is great demand.

The world's supply of wheat in 1906 amounted to about 3,423,134,000 bushels. Of this amount Canada produced 131,614,000 bushels. The United States produces at the present time more wheat than any other country in the world. Its product in 1906 amounted to about 735,261,000 bushels. Following in order of amounts produced are Russia in Europe, with 450,000,000 bushels; France, 324,725,000 bushels; British India, 319,586,000 bushels; Austria-Hungary, 268,574,000 bushels. Other wheat countries are Australia, Argentine

Republic, Russia in Asia, Spain and Germany. Great Britain produced in 1906 about 62,000,000 bushels. It is estimated that in Canada it requires for each person about 5.5 bushels of wheat. This amount includes that used for food and for seed. In Great Britain it requires about 5.6 bushels; United States, 6.23 bushels. In Russia only about 2.5 bushels are required, but no doubt rye also is used for food by the Russians.

EXERCISES

1. Lay a head of wheat on your desk and make a drawing of it.
2. Shell a head and lay the kernels from each spikelet side by side, with germ end downwards, in the order you take them from the head. Make drawing to represent the arrangement.
3. In what part of the head are the largest kernels situated? The smallest?
4. What part of the head produces the largest number of kernels?
5. Shell ten heads and find average number of kernels to a head.
6. Find out how many stalks come from one seed. A number of stalks coming from one seed is called *tillering*.
7. How many seeds of Red Fyfe does a farmer sow on an acre?
8. If each kernel grew and produced three stalks each, bearing an average head such as you have counted, how many bushels of wheat would each acre produce?
9. What was the average number of bushels produced per acre in your province last year? How many bushels did your farm produce?
10. How do you account for such low yields?

III. WHEAT CULTURE

The Seed-bed. The wheat plant makes certain demands if it is to do its best in the way of producing a heavy crop of high quality grain. One of these demands, and a very important one at that, is a good seed-bed. Now, what constitutes a good seed-bed? The soil must be in the best kind of tilth; it must be firm and it must be moist. These are three essential conditions to the best success in wheat culture, where fertility is ample and the climate is suitable.

The first condition in which the new settler finds the great wheat fields of the West is that of prairie sod. This sod is of different kinds, according to the character of the soil and whether it is treed or treeless. Over a large portion of the southern and western part of the prairie belt the surface of the soil is hummocky. The soil itself is heavy clay, covered with a coating of decayed vegetable matter from the wild prairie grasses and other plants. During the dry seasons of the year, the clay cracks and leaves octagonal-shaped solid patches about four to six feet in diameter, sometimes called melon beds. When the rains come the clay swells and closes up the clefts. You have noticed these clefts, perhaps, where a cellar, well or ditch is being dug. You have seen the black streaks of vegetable soil extending downwards for

several feet. The vegetable mould was carried into the clefts by wind and water. This hummocky land is difficult to manage at first. It requires the most sensible kind of treatment in order to secure a good seed-bed for wheat. Most people are, at the outset, in too great a hurry to get in a crop and do not take time to find out the best method of treatment, and in their haste they spoil their chances for good returns for a number of years. It has been found by years of experience and practice that the best method in dealing with tough, hummocky prairie, and in fact any prairie with tough sod, is as follows: Some time in May or early in June, during our rainy season, the land should be broken very shallow, say about two and one-half to three inches, with a twelve or fourteen inch walking plough, termed a breaker. The furrow turned over should lie right flat on the furrow sole. This can be improved by running over it with a roller or packer. The moisture, heat and air aid in decomposing the sod, and as soon as this decomposition is completed (usually in July or August), the land should be backset. Backsetting is accomplished by ploughing about three inches deeper in the same direction as before. This makes a reservoir for holding moisture and does away with clods. A disk is then used for pulverizing and mellowing the seed-bed. This is followed by the packer and harrow.

In some sections of the country where there is more or less scrub, and where the sod is thin, the practice of deep breaking is followed with good success. By deep breaking is meant that the land is ploughed about four inches deep some time in May and early June, disked and packed. In July and early August it is disked and harrowed to put it in good condition for the seed-bed next spring. Where new settlers adopt the practice of breaking and backsetting, if the work is done carefully, they are sure of two good crops from the land the second and third years they occupy it. There is more or less danger of losing the second crop on deep breaking, should the second year happen to be dry. There will not be sufficient moisture stored to carry the crop over the dry period in late July and August.

In some parts of the country, especially on the newer, heavier soils, the second crop of wheat is sown on the stubble land. The practice in such cases is to burn the stubble in the spring when a warm wind is blowing from the south. The wheat is then drilled into the previous year's firm seed-bed, after which the land is given one or two strokes with the harrow. This practice is perhaps defensible on our new, rich soils where new settlers with limited means are getting a start. This method, too, gives them their surest crop, as it matures earlier and produces a higher quality of

grain. It is, however, wasteful in the end, for it robs the soil of humus. Burning the straw leaves on the soil nothing but the ash, which has little water-holding capacity, and furnishes no nitrogen for the growing crop. In time this practice of burning the stubble must surely give way to more substantial methods. In Manitoba very little stubble is burned. Much of it is incorporated in the soil, to prevent the soil from drifting and to restore the wasted humus.

EXERCISES

1. Describe a seed-bed best suited to wheat.
2. Two fields are prepared alike for wheat, except that one is packed lengthwise and crosswise at a cost of fifty cents an acre. The packed field is ripe four days ahead of the unpacked field and yields thirty-five bushels per acre of No. 1 Northern, whereas the unpacked field is frozen and yields eighteen bushels of feed. Compute the approximate amount of gain to the farmer who packed a 200-acre summer fallow at prices as quoted now.
3. Name the advantages of having a firm seed-bed for wheat.
4. How deep should wheat seed be sown?
5. What are the advantages gained by having a wheat seed-bed free from weeds?

IV. WHEAT—THE SEED

Selection. You have already learned that the seed contains a little plant lying asleep, all wrapped around with food and protected by tough, tight

coverings. Now, in order to insure good strong healthy plants, you must look first to the selection of strong seed. The outward indications of good seed are size, plumpness, color and in some cases lustre.

Large seeds are desired because they contain larger embryo plants and larger amounts of food to nourish the young plant while it is taking root and getting itself established in the soil and air. Take a handful of Red Fyfe wheat, and from it select ten large, plump, ten medium and ten small kernels. Plant these two inches deep in rows in a box of moist soil. Do the same thing with ten large, shrunken, ten medium and ten small kernels. Watch the results and note the comparisons in length and strength of plants as well as the time it takes them to germinate.

The color indicates the health of the seed. Seeds may be injured by frost, dampness, fungous diseases and sprouting. Examine different samples of seed for such injuries. The farmer's chances for a good crop are very much lessened if he sows weak seed from any of the causes mentioned. Get samples of frosted grain and note the appearance of the outer skin. Do the same with wheat that has been dampened in the bin. Wheat seeds sometimes sprout in the stook and at other times in the bin. Examine such seeds and test for germinating powers.

In selecting seed it is well to see that you are getting it true to variety. It is not good practice to sow Red Fyfe and Preston mixed, because Preston ripens from three to four days earlier than Red Fyfe. You will be able to give other reasons why this should not be done.

Selection is done in different ways. If you wish to get started with good pure seed, select a few of the best plants you can find in the field that are true to the variety you wish to grow, and sow the seed from these plants by itself in the garden. Let the plants get dead ripe before you cut them and carefully save the seed. It will not be long till you have enough pure seed to sow your whole farm. From a single seed more than 300,000 bushels of wheat were produced in Minnesota in ten years.

The fanning mill is the method used by the farmer for selecting large plump seed, but this will not cull out the seeds of different varieties, nor will it separate the seeds of good and poor plants. All other kinds of grain, such as oats and barley and weed seeds, should be cleaned from the wheat. Any of these growing among the wheat and threshed with it, tend to depreciate its value.

Testing. It is well to know beforehand something about the germinating powers of the seed we are going to sow. On account of so many conditions that may affect its ability to grow, we

should test samples of the seed as directed in Lesson XXIV, page 87, Nature Study. If the conditions of moisture, warmth and air are right, ninety per cent. of the seed should germinate strong in four to six days.

Treating the Seed. We are all familiar with the great losses that are sustained every year by the farmers through the presence of stinking smut in the wheat. Not only does it injure the quality of the product and reduce its value, but it also diminishes the quantity, so that the producer is sustaining a double loss. We have a means at hand of preventing this smut, which results in a loss of hundreds of thousands of dollars to Canada alone every year.

Scientists have found out that smut is a fungous plant that grows from a little spore. This spore may be already in the ground or it may be clinging in some place to the kernel of wheat. They have found out, also, that this little spore can be quite easily destroyed by thoroughly *disinfecting* each grain of wheat. The different *disinfectants* used are hot water, formaldehyde, copper sulphate solution and corrosive sublimate solution. The one that has been found most effective for wheat is the formaldehyde treatment. Formaldehyde is purchased from the druggist as formalin, 40 per cent. strong. One pound of this liquid is mixed with forty gallons of water. The wheat may be

immersed in the solution, or the grain may be piled in a long heap on the granary floor and thoroughly sprinkled, shovelled into another heap and sprinkled again, and again covered for two hours. The reason for this thoroughness is to make sure that every grain is covered with the liquid; then we know that all smut spores have come in contact with the disinfectant and are consequently destroyed. The bags in which the seed is carried to the field should be disinfected and the seeder box washed with the liquid.

Sowing the Seed. Different kinds of drills are now used for sowing wheat. Of these there are the shoe, hoe, tube, double and single disk drills, all used to good advantage on different kinds of soils under different methods of treatment.

Depth to Sow. The depth to sow wheat will depend almost entirely upon the moisture condition of the soil. If you place the seed in dry, loose soil, it must wait for the moisture before it can make the first start towards germination. It may be for weeks lying in this resting condition, and as a result its period for growth is much shortened. If it is sown too deep there is a loss of time again, for it takes so long for the young plants to reach the surface of the soil, and many die in their efforts to do so. Then, too, the plant will throw out a second whorl of roots at the water line, or just at that place where the dry soil rests

on the moist soil. This imposes extra work upon the plant and lengthens the period of maturity. From this we learn that there is just one depth to sow wheat seed, and that is on the moisture line. The water line should be about two inches below the surface of the soil.

After Tillage. Time to Sow—Spring, Fall. There is a time, no doubt, each season when the conditions are most favorable for sowing wheat. It is impossible, however, on account of the large acreage which we have to put in, to take advantage of just the right time when we can put the seed in warm, moist, compact, well aerated soil. So we must start a little earlier in order to finish in time to give the plants sufficient time to mature before there is danger of early frosts. In this year, 1909, there was wheat matured in ninety-one days, but the average over the wheat area was about one hundred and twelve days.

Fall wheat requires to be sown early enough so that it can make a good growth of root and stem before the freeze-up. The conditions appear to be best about the third or fourth week of July.

After wheat has been sown it is not often that it is given any further attention so far as tillage is concerned. However, there are two implements that may be used on wheat sometimes to advantage. One of these is the surface packer. This may take the form of a roller or of a corrugated packer.

Neither of these can be used when the ground is wet, for injury would be done to both the soil and the crop. The corrugated packer is better than the roller to use in this case, because it leaves the surface rough and in a loose mulch, while it has firmed the soil around the roots of the plants. It is best used where a crust has formed over the field after a rain. It breaks this crust and forms a mulch which prevents evaporation. The packer may be used when the wheat is three to four inches high. The action of the packer seems to stop the growth for a few days while the plants take deeper root. Other noticeable results are shorter, stronger straw and earlier maturity. The harrow is sometimes used with good results on wheat. A tilt harrow, with the teeth turned back slightly, is effective in breaking up a crust and forming a mulch. A large number of weeds, such as mustard, lamb's-quarters and pig weed, that have germinated near the surface may also be uprooted. This operation is one that should be performed with the greatest care, as much damage may be done to the crop by a careless or incompetent driver. Only one who understands clearly the objects to be accomplished should attempt it. If carelessly done much may be uprooted, and at the same time maturity may be delayed until frost destroys the crop.

Harvesting. On our large acreage the wheat



CORRUGATED LAND PACKER MAKING A FIRM SEED-BED.



DISKING TO KILL WEEDS AND PULVERIZE SEED-BED.

harvest must start early in order to avoid the loss that would accrue through shelling from that which would be cut last. Many farmers are guided in this by the conditions of rankness of growth, maturity, and lateness of season. It is carefully tied in bundles and stooked so that the process of ripening may still go on. Too rapid drying in the stook is not the best thing for the wheat. It is necessary that the sheaves all stand up well, and that the stook be capped. When this is carefully done the farmer is almost sure of a good quality of grain. This allows the sap to travel up from the stem and carry food to the kernels in the head, and thus the ripening processes are completed after cutting, and the hard, flinty, red grains so characteristic of the best quality of wheat are produced. If the grain is cut green and the stooks not capped, the drying is so rapid that only small, shrivelled kernels are the reward of the farmer's labors.

Stacking. In some sections the grain is all stacked, in order that the fall ploughing may be done before the ground freezes up. Where grain is threshed from the stack there is much less danger of scattering weed seeds over the fields.

Care must be exercised in building stacks in order to insure against the danger of having musty, sprouted grain in case of rainy weather. Many men take a great pride in being able to build a well formed stack that will stand against

the wind, shed the rain and thresh out a high quality of grain.

EXERCISES

1. Describe the kind of wheat seed a farmer should endeavor to sow.
2. What is the best means of securing good seed?
3. What are the advantages of the fanning mill in securing good seed? What the disadvantages?
4. What are the outward indications of a good wheat seed? Give reasons for your answer.
5. Let pupils bring samples of wheat, oats, barley, peas and flax from home, and examine them for size, color, true-ness to type and variety, and freedom from weed seeds.
6. How much formalin does it take to treat 100 bushels of wheat?
7. How long will it take two men to treat 100 bushels of wheat?
8. Find out what it will cost per bushel to treat with formalin for the prevention of stinking smut.
9. What is the difference in the price received by the farmer for wheat that is badly smutted and wheat that is free from smut?
10. How much will a man gain on 100 acres yielding 25 bushels per acre, by treating his seed with formalin or bluestone, over his neighbor who has an equal amount of badly smutted wheat?

V. SUMMER FALLOWING.

A summer fallow is a piece of land that is cultivated and kept without any crop growing on it during the summer season. Summer fallowing

is a very old practice in agriculture. Hundreds of years ago in Egypt, Greece and other agricultural countries the farmers adopted and practised this system with the idea of resting the land and giving it an opportunity to enrich itself in the elements of plant food. Wheat was their principal crop, and they found that the continual cropping of one kind of grain impoverished the soil and rendered it incapable of maintaining even an average yield. It was on this account that summer fallowing became common in many of the European countries, and even in England, where it was followed till along in the eighteenth century. The increased population called for more food products, and changes in the methods of owning land made it necessary to introduce some system that would do away with the wasteful practice of allowing so many acres—about one-third of every farm—to lie idle every year.

It happened in the early part of the eighteenth century, that clover and lucerne were introduced into England for pasture and hay crops. It was found that these plants left the soil with increased fertility stored up for succeeding crops, and as a result they became very popular among the farmers. Stock raising and stock improvement became general, and much attention was paid to the raising of crops that would afford better nourishment for horses, cattle, sheep and swine. Roots—turnips

and mangels—were introduced as regular crops, and in a short time summer fallowing was done away with, except in rare cases. Other countries, notably the Netherlands and Prussia, followed England's example. In the Eastern States and in the older provinces of Canada summer fallowing was resorted to in order to restore fertility to run-down soil and fit it for a good crop, but now a suitable rotation of crops has supplanted this system, and much better returns are being realized from the land.

Early in the history of the agriculture of the prairie provinces summer fallowing was found to be most advantageous in safeguarding the future crop. It may be in place here to perpetuate the name of the man who instituted, practised and preached this system until it has become a fixed practice in our method of agriculture.

Mr. Angus McKay, superintendent of the Dominion Experimental Farm at Indian Head, was in 1885 a farmer tilling his own soil at that time. Men and teams, owing to the Rebellion, were scarce that summer, and as a result he was able to sow only a part of his land. He spent the month of June and early July preparing land for the next year's crop. The year 1886 was very hot and dry, and many of the crops on fall and spring prepared seed-beds were not worth cutting. Mr. McKay threshed twenty-five bushels to the acre, and from

that time till now it has been the practice of the farmers of southern Manitoba, southern and western Saskatchewan and southern and eastern Alberta, to prepare about one-third of their ploughed land the year previous to its being sown. In eastern and northern Manitoba and northern Saskatchewan and Alberta, where there is more rainfall, and where more stock is kept, the farmers are able to keep most of their land under crop, and summer fallow only when it is absolutely necessary in order to rid their fields of noxious weeds.

It is well for us to study briefly the principles underlying the system of summer fallowing, together with the advantages and disadvantages of the same, in order that we may practise the most intelligent methods on our own farms after we have considered carefully all the conditions that exist there.

From what has been referred to above, you will observe:

1. That the farmer on an ordinary grain farm has time during June and July to prepare a seed-bed for early sowing the following spring.
2. That a good paying crop was harvested in a very dry year from land that had been summer fallowed the previous year.
3. When land is properly summer fallowed weed seeds are germinated and several crops of weeds killed.

4. The best kind of firm seed-bed can be made.
5. Moisture is stored from one year's rains for the next year's crops.
6. Work is provided for men and teams at a time when there is little else to do on a strictly grain farm.

The disadvantages of summer fallowing are as follows:

1. The summer fallow produces a weaker growth of straw, and as a result there is danger of loss through lodging and rust. The rank late growth defers maturity and there is danger of further loss from early fall frosts.
2. The practice is wasteful of humus, one of the most important constituents of the soil. As a result the soil loses its water-holding capacity, together with its chief nitrogen supply. In addition the soil becomes reduced to such fine particles that it blows readily and occasions much loss to the young plants that are just nicely above the ground, and at the same time carries much fertility away to the fences or roadsides, and there piles it up in drifts. The loss of humus spoils the physical condition of the soil, rendering it sticky when wet, hard and brick-like when dry, difficult to till at any time, and at all times a most uncharitable seed-bed.
3. In some places it is urged that summer fallowing is a wasteful, extravagant practice, in that

the land is lying idle while it might as well be bearing a crop of grass, clover, corn or roots. This objection would be urged especially in sections where there is plenty of rainfall.

Since so large a portion of the country is dependent upon a limited amount of moisture that must be stored up the year previous for the growing crops, it is necessary that we employ the best methods in making our summer fallows.

Our rains usually come in June, and it is then that weed seeds germinate and grow rapidly. We wish to catch and hold the moisture and at the same time germinate and kill the weeds. To accomplish these ends we must plough in June and not later than the first week in July. The following method has been found best on the Dominion Experimental Farms at Indian Head and Brandon, as well as on a large number of farms throughout the country:

McKay System of Soil Tillage (better known as summer fallowing). "The land should be ploughed six to eight inches deep early in June and then packed and harrowed immediately and followed at intervals with surface cultivation. The ploughing makes a reservoir for holding water. The packing breaks down lumps and closes up the open spaces, making the soil more compact. The harrow packs the soil and leaves a granular mulch or blanket which prevents to a great extent the

evaporation of moisture. You will remember in another lesson how it was explained that weeds pump large quantities of moisture out of the soil. The farmer should bear this in mind when making his summer fallow, and prevent the wholesale loss of moisture by keeping the soil free from weeds during the summer season. This is done by frequent surface cultivation with harrow or cultivator, according to the nature of the weeds to be destroyed."

To this we should add fall and spring tillage. As soon as possible in the fall, after the crop has been removed by stacking or threshing, disk or gang plough, shallow, the land that is to be summer fallowed. This will cover up weed seeds and at the same time form a mulch that will conserve the moisture of the soil. Not only will it conserve the moisture, but it will aid in the capillary rise of moisture from the lower three or four feet of soil to the zone near the surface, where its benefits will be felt in several ways. This moisture near the surface will give the frost a greater opportunity to granulate the soil and it will aid in the germination of many weed seeds—a few, perhaps, in the fall and a greater number in the spring. Again in the spring, as soon as weed seeds start, this land should be again disked, both killing weeds and forming a mulch. If disking can be followed with the harrow, better results will be

obtained. This operation may be engaged in as often as time will permit before the ploughing is done in June.

As to how often the land will require to be summer fallowed will depend upon the local conditions. In some localities once in three years, and in others once in two years, depending upon the amount of rainfall and nature of soil, and in others only when necessary to kill some bad weed, such as perennial sow thistle, Canadian thistle, quack grass, and weeds of like nature.

EXERCISES

1. What is meant by a summer fallow?
2. When is it necessary to summer fallow?
3. Write a short story of the early history of summer fallowing.
4. When is the proper time to summer fallow in this country? Why?
5. What processes constitute summer fallowing?
6. Find out at home what it costs to summer fallow 100 acres of land. Get cost of each item of work, such as ploughing, packing, harrowing, cultivating, etc.
7. What are the advantages and what the disadvantages of summer fallowing?
8. In what parts of this country, if any, can it be done away with to a great extent?
9. What will take its place?
10. Is it good practice to let a crop of weeds grow up on a summer fallow? Why?

VI. THE POTATO

The potato belongs to a very large family of plants called *Solanaceæ*. In the same family are the tomato and tobacco plants; one grown for its fruit, and the other for its leaves. The potato is grown for its tubers, which are used as food for man and animals, and for the manufacture of starch and alcohol. The tuber is an underground stem having *eyes* or buds. It is called the *seed* because it is from it that the variety is perpetuated. The tubers when analyzed yield about 75 per cent. of water, and nearly 20 per cent. of starch; about 2.5 per cent. of protein, a small amount of ash, fibre and other substances. The fibrous roots extend from two to four feet down in the ground and often two feet sideways from the hill. The stems, or vines as we sometimes call them, bear a great number of large green leaves. On the tips of the vines the blossoms are borne, and finally in their places the ripened fruit in the form of small round bodies full of pulp and seeds. If these seeds are planted we are likely to obtain many new sorts of potatoes very different from those we planted.

It is believed that the potato is a native of Uruguay and Argentina, in South America. The Spaniards cultivated it for purposes of food. When Sir Walter Raleigh's expedition was returning from America it brought some potatoes back with it to

Ireland, where the potato has been one of the chief articles of diet ever since. Later it was taken back to New England by colonists, and from Ireland it was taken to England and Europe, until now the potato is one of the largest single crops grown as a food, exceeded only by that of rice.

It thrives best in cool countries, so we should expect to find it at its best in Northern Europe and America. Enormous yields are reported in some European countries, even as high as 1,000 bushels per acre.

The Seed-Bed. The soil best suited to potatoes is a deep mellow loam containing a large amount of humus. Heavy clays are objectionable both from the standpoint of quality and yield. While a medium heavy yield may be obtained on clay soil, the potatoes are usually ill-shaped and lacking in flavor and mealiness.

The best seed-bed is obtained by deep ploughing as early in the spring as possible, followed by the harrows at intervals of six to eight days, to kill weeds and conserve moisture, up to about the 20th of May, when the land may be ploughed again about four and one-half inches deep. Old sod is not the best place for potatoes, as it is often infested with wireworms or white grubs, which injure the crop.

Selection of Seed. The kind of seed planted will depend much upon the use to which you are going

to put the crop. If for early marketing, then you will plant the earliest variety obtainable. And in any case we should endeavor to procure an early maturing variety on account of our shorter season and the danger of both late spring and early autumn frosts. The tubers should be true to variety and free from knobs or second growths. We all like a medium-sized, smooth potato, whose buds are fairly even with the surface. The seed tubers should be spread out on a warm light floor for about two weeks in order that the buds may start. This will hasten the growth when planted and shorten the period of maturity.

It has been found out by careful investigators that a set about the size of a hen's egg with one or two eyes will give the largest and most profitable crop. Cuts of this description can be made only by hand. Machine cutters make no distinction and as often cut through the buds, thus destroying their ability to become strong, stocky plants. The eye should be as near the centre as possible, with a good amount of starchy food behind it, to feed the young plant and give it a good start while the roots are reaching out and establishing themselves for future usefulness.

Treating the Seed. If the tubers from which the seed is selected are scabby, or if the ground upon which the potatoes are to be planted has grown scabby tubers before, then the sets should be

treated with formalin to destroy the spores that produce the fungous growths, just as you treated the wheat seed to destroy smut spores. Scab spores are more difficult to kill, and therefore harsher treatment is recommended. The seed should be immersed for two hours in a formalin solution of the strength of one pound of formalin to thirty gallons of water. The seed should be planted immediately after treatment, or spread out thinly on a floor to dry.

Planting. About the 20th of May the soil is again ploughed about four and one-half inches deep, and the sets may be dropped in every third furrow about twelve to fourteen inches apart, and covered with the next furrow. Where planting is done on a larger scale, a potato planter is used. This is an implement drawn by two horses. It is so arranged that it drops and covers the sets the desired depth with remarkable precision and accuracy. This machine will plant eight or nine acres a day, and does much to lighten and hasten the work of putting in this crop. Boys and girls will be glad to know there is such a back-saving implement, though it is too expensive a machine to have where only a small plot is to be planted.

After-cultivation. After planting is completed, the diamond or spike tooth harrow should be used often enough to kill weeds and maintain a mulch until the stalks are about four inches high. Har-

rowing will do the stalks no harm up to that time, but will do an immense amount of good. Surface, flat cultivation until the vines nearly meet in the rows will ensure a good crop of tubers. The cultivation should be deep at first, and gradually shallower as the roots extend out from the plants.

Protection. The potato vines have as yet required little protection, though in some places the larvae of the Colorado beetle or potato bug, as it is sometimes called, have done quite a bit of damage to the foliage. The beetle lays its yellow eggs in clusters on the under side of the leaf. When the young hatch out, they set to work at once eating the leaves. They may be poisoned easily by spraying the plants with a solution of paris green made by mixing 4 ounces of paris green and 4 ounces of lime with 40 gallons of water and applying this at the rate of 200 gallons per acre.

Harvesting. When potatoes are grown for early market they are dug as soon as they are large enough and sold for early table use. But if the tubers are to be kept over winter, the stalks should be allowed to die before digging takes place. If the stalks are killed by blight, the digging should be delayed ten to twelve days after the stalks have turned brown.

The digging may be done in different ways. The old method was with a hoe or a fork, but this is too slow and too laborious where a large plot

has to be dug. The plough is used to good advantage in turning them out, after which the ground may be harrowed and cultivated to uncover some tubers that may be hidden from the sight of the pickers.

Where large acreages are to be harvested, the potato digger is the most economical implement. It digs, sorts, and sacks the tubers and makes the work of harvesting very light as compared with the older methods.

Storing. The best place to keep potatoes is in a cool, dark, well-ventilated cellar, at 32° to 40° Fahr. Stored in this way they can be easily looked after and sorted in case rotting or heating should take place.

If large quantities are raised and the cellar is not suitable, then they may be stored in a pit by scooping out a long narrow trench about 12 to 14 feet long and 4 to 6 feet wide, and 8 inches deep. Heap the potatoes in this and cover them with a layer of straw and then about four inches of clay or earth. Let this freeze, and cover with another layer of straw and another layer of clay as before, and allow to freeze. Then cover with a heavy coating of coarse strawy horse manure or oat straw, about seven feet out from the pit. Be sure to arrange ventilators in the top of the pit. Two 4 by 4 wooden pipes running down into the pit will be sufficient. You know there is great

danger of the potatoes heating and spoiling if these ventilators are not properly put in. So we should be careful of this, as it will mean the saving of our crop.

EXERCISES

1. Compare potatoes brought by different pupils, noting size, shape, number of eyes, depth of eyes, roughness or smoothness of skin.
2. Make three-ounce cuts suitable for seed, taking care to preserve a strong bud well-furnished with starchy material to feed the young shoot.
3. Sprout different potatoes in the light, and note strength of growth.
4. Select tubers from good yielding plants and use for seed next year. Note results.
5. Leave a few hills of potatoes in the ground over winter. Leave stems in alternate hills. Note effects of winter frost on ability to grow and on quality.
6. Try potatoes planted in hills on the level and note any difference in yield or size of tubers.

VII. CLOVER AND ALFALFA

CLOVER

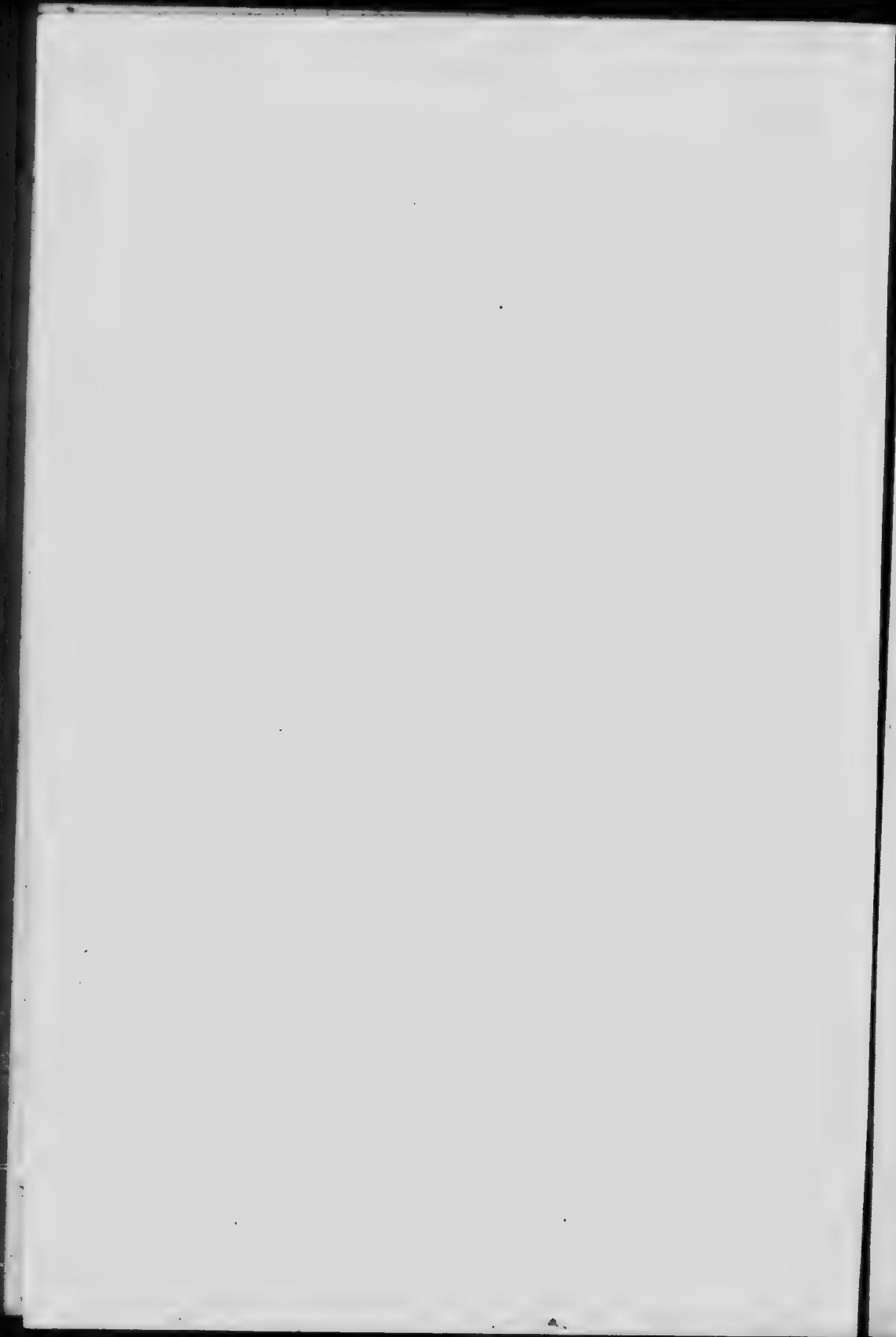
Clover belongs to a family of plants known as legumes. In the same family are also included peas, beans, vetches and many other kinds of both cultivated and wild plants. Clover is grown principally on account of the amount of food furnished by its stems and leaves for live stock. It



PICKING CULTIVATED STRAWBERRIES IN THE PRAIRIE PROVINCES.
Every home should have a fruit garden.



A CULTIVATED RASPBERRY PATCH IN THE PRAIRIE PROVINCES.



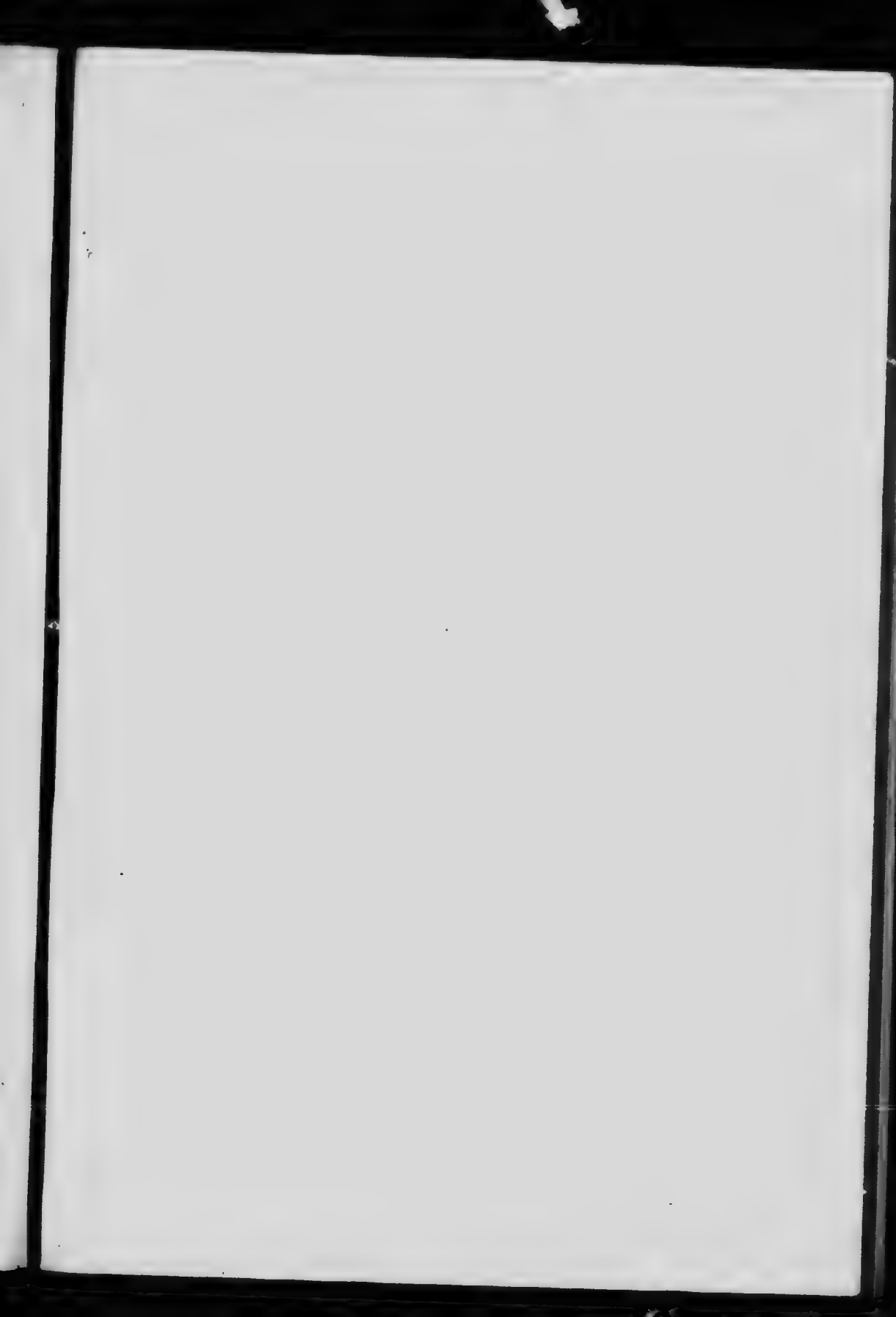
is used for both pasture and hay, and is on this account called a *forage* plant. It is valuable not only as a forage plant, but also because of its benefit to the land upon which it grows. The surface soil upon which clover grows is richer in the elements of fertility, especially nitrogen, due to the work of bacteria and to that of the long roots, which gather other elements as well from great depths in the subsoil and leave them near the surface. The leaves that fall upon the ground are rich in ash materials. Vegetable matter is added from the roots and leaves. The roots have very desirable physical effects upon the soil, leaving it easier for both air and water to penetrate.

Clover was introduced into England from France about 1650 and was later brought to America. In the eastern provinces of Canada and in many of the states to the south, the clover family furnishes a large proportion of the forage, being exceeded in some parts by corn alone, and that in the middle-western states. Clover is gradually getting a foothold in Manitoba, especially in the Red River Valley and in the more timbered parts. In Alberta alfalfa is already being grown quite extensively on the Experimental Farms, and in a small way by farmers. In Saskatchewan clover and alfalfa have been grown for years on the Dominion Experimental Farm at Indian Head; and here and there throughout the province

farmers have grown small plots as an experiment. We shall look forward to the time when these crops can be grown in large acreage over this country. When we have learned how to grow clover and alfalfa and when the hardiest varieties have been introduced, these crops will constitute an important resource as forage plants, and also as restorers of fertility lost by continual grain cropping. It is safe to predict that some day alfalfa and clover will be among the most valuable crops grown in the prairie provinces. The hay made from well-cured clover or alfalfa is very rich in the elements that form blood, muscle, milk, eggs, wool, hair and hoof, and on this account is valuable as a food for all classes of live stock, by which it is much relished. These feedstuffs take the place of bran to a large extent—about a pound and a half of alfalfa being equal to a pound of bran in feeding value.

ALFALFA

Culture—The Seed-bed. The most suitable soil is well drained clay loam with a gravelly subsoil. Where lime is deficient in the soil these crops do not thrive. Nor will alfalfa grow where the air spaces in the soil are filled with water. It is a very deep-rooted plant, and if given a chance will send its roots down twelve to fifteen feet to water. This character makes it a valuable plant in dry climates.





RUSSIAN POPLAR WINDBREAK PLANTED FROM CUTTINGS.
Enclosing 20 acres, showing four years' growth. An excellent shelter belt for farmstead and fruit garden.



HOME SURROUNDINGS PROTECTED AND BEAUTIFIED.

The seed-bed should be fine and firm and well stored with moisture for germinating purposes. The seed is small, and unless it is placed in moist soil it will lie for a long time waiting for the necessary moisture in the form of rain. A good summer fallow makes the best seed-bed, while potato, root, or corn ground is good on account of the mellowness and freedom from weeds. The good summer fallow, of course, is preferred on account of the stored-up moisture. All weed seeds should have been germinated and destroyed, as weeds growing among alfalfa rob it of the moisture that it needs to give it a good start before winter comes on. If put on spring ploughing the ground should be well packed and harrowed before and after seeding.

Selection of Seed. In selecting alfalfa seed the same care should be taken as with wheat or other plants.

1. A hardy drouth-resisting variety is most desirable for this country.

2. It should be true to variety.

3. The seed should be plump, bright yellow, or yellow and violet in color, and strong in germinating powers.

4. It should be free from weed and other seeds.

Before purchasing the seed a sample should be examined and tested in order to make sure that the four requirements are fulfilled. The second requirement might be rather hard to determine

from looking at a sample of clover or alfalfa seed, but in this case, if the other requirements are met, the guarantee of the seedsman might be taken. The testing is done similar to that of wheat. Care must be taken to keep the seeds moist but not covered with water. The seeds may be placed on wet blotting paper on a plate and kept in a warm (not hot) place. It takes about the same length of time for these seeds to germinate that it does for wheat, corn, oats and barley.

Sowing. The seed should be sown at the rate of twenty pounds to the acre sometime during June or the first week in July, in order that it may receive a good wetting from the showers that come at this time of year. It may be sown by hand, but it is better done by a broadcast grass seed attachment on the drill or by a barrow seeder. It may be sown in drills with oats, wheat or barley. This is not a safe practice, however, in this country, because the wheat, oats and barley germinate quickly, send their roots out in all directions and rob the little alfalfa plants of the moisture and dissolved plant food. You have seen the big chickens rob the little ones, and the big calves rob the little fellows when fed in the same troughs. The little ones get stunted and sometimes die from starvation. So it is with alfalfa and clover if sown with other plants where moisture is likely to be scarce.

Cultivation. After sowing, the ground should be harrowed and then packed with a surface packer to firm the soil grains around the seed in order that they may help to draw water to the seed.

Protecting. Should weeds come up with the alfalfa, something must be done to give them a setback and prevent their doing too great injury to the crop. When alfalfa is ten to twelve inches high, the tops of the weeds should be cut off with the mower. This may be done a second time. In this way the weeds will be prevented from going to seed, and the alfalfa will be given a chance to get ahead. The cuttings are better left on the ground to prevent the evaporation of moisture.

Animals must not be allowed to eat off the crop the first year. It requires all the growth it can make to carry it through the first winter and spring.

Harvesting. In this country we should get at least two cuttings of excellent hay. In some places in the states to the south—Kansas, Colorado, Arizona, and California—they get from three to nine cuttings. Alfalfa should be cut when the plants are about one-tenth in bloom. The leaves are much richer in protein than bran, and it is the leaves we have to be careful about saving when making hay. It is usually cut in the forenoon as soon as the dew is off, and allowed to wilt a little, when it is raked in windrows and

put in small cocks before evening. If it is cured sufficiently, it may be drawn in and put in the stack or mow the next day. When there is too much moisture left in the stems there is danger of the hay spoiling. Sometimes from heating the hay catches fire. This, however, seldom occurs.

After-care. Providing the conditions are right, alfalfa lives a number of years, and on this account is called a perennial. If it comes out all right the second spring, the ground should be cultivated with a disk fairly early before there is much growth, or it may be done after the first crop has been cut. The disk should be set nearly straight and loaded so as to cut about three inches deep. When disked one way it should then be done at right angles and afterwards harrowed with a straight-toothed harrow. The disking is done for two purposes—one is to open the soil and prepare it for catching the rains, and the other to cut the crowns of the alfalfa plants. The harrow smooths the surface and leaves a mulch to protect the moisture from evaporation.

Precautions with Stock. Alfalfa makes an excellent pasture for hogs and in fact for any kind of stock, but much care must be exercised in its use as such. Alfalfa is very liable to cause bloating that may result in death. To prevent this, animals should not be turned on alfalfa when the plants are wet from dew or rain. Animals, except hogs, should

be full of dry feed when turned on alfalfa or clover for the first time, and should have the run of an old pasture at all times when feeding upon alfalfa pasture.

Alfalfa should not be pastured too close by stock, or they will kill it by eating off the crowns from which the stems grow.

EXERCISES

1. What plants of the Legume family grow in your locality?
2. What are the plants you have named used for?
3. What effect do they produce upon the soil?
4. Has clover or alfalfa been tried in your neighborhood? With what results?
5. Why do these plants not grow well in all soils?
6. What can we do to help clover and alfalfa to get established?
7. What advantage would clover and alfalfa be to our agriculture?
8. What precautions must be taken in making alfalfa hay?
9. What precautions should be taken before sowing alfalfa seed?
10. Tell how weeds are injurious to young alfalfa plants.
11. Why should farmers in the prairie provinces make efforts to grow a leguminous crop, such as clover, alfalfa, or peas?
12. Review the lessons on Seed Testing, Bacteria, and Seed Germination.

VIII. GRASSES

We watch for the grass to come in the early spring and cover the brown prairies, the yards and the dusty roadsides with a carpet of beautiful green. How glad we are at its first appearance! The animals, too, rejoice, for they know that it means that they are soon to have their freedom to roam about over the pastures and partake at will of their most pleasing and satisfying food. While its beauty pleases us, it is not for this alone that we prize it. It is of great commercial value to the farmers of the country. Some countries are specially noted for their production of grass. England for years has been famed for her luxuriant grassy lawns and pastures; Kentucky, Iowa and Illinois for their blue grass pastures. Any country that attains agricultural fame and remains permanently great as an agricultural country will most assuredly do so because of its ability to grow good grass.

Generally speaking, alfalfa and the clovers are spoken of as grasses, but this lesson is intended to deal only with the true grasses. These belong to a family of plants called *gramineæ*. There are a great number of different kinds of grasses. They differ in their roots, stems, leaves and seeds, in their likings for certain soils and climate, in their ability to stand drought, in their yields per acre, and in their nutritiousness and palatability.

Uses of Grasses. Grasses are used most extensively for pastures. A good pasture grass should form a close sward, commence growth early in the spring and continue green till late in the fall, especially if it is intended for spring, summer and fall feeding. Where a grass is intended for winter pasture, it is essential that it should mature early enough to escape the fall frosts, else it will lose much of its nutritious qualities. Some of the valuable pasture grasses other than the native prairie grasses are brome grass, English fescue, improved western rye grass, Kentucky blue grass and Canada blue grass. Grasses are also used for the purpose of making hay which is used especially for feeding to stock in the winter time, and to stock that is kept up during the other seasons of the year. The grasses used for hay making are brome, western rye grass, English fescue and timothy. No doubt more of our native grasses will be selected and improved for both pasture and hay-making purposes. Grass is also used extensively for making lawns about our homes. Those used for lawn making are mostly Kentucky blue grass, Canada blue grass and English fescue. Grasses are especially useful on our Western farms on account of the root fibre which they add to the soil, thus preventing the drifting which occurs on land that has been intensively summer fallowed and cropped with wheat for a number of years.

Our people as yet have given little attention to grass growing, but this question is now forcing itself upon the attention of our farmers, and hence, we should inform ourselves regarding the grasses that are best suited to our soils and climate, the methods which should be employed in seeding them, and the care and management of the grass fields.

Brome Grass. Brome grass has been highly recommended to the farmers of the Central West, both as a drought-resister and as a soil-binder. This is a perennial grass. It has running root-stalks with a great system of fibrous roots that extend deep into the soil, where they gather moisture and food for the plant. On account of its running root-stalk and perennial character, it is disliked by a great many farmers, as it is very difficult to eradicate it from the fields when once it is established. Farmers who understand it have little difficulty in eradicating it where it has been sown on the lighter land or in the prairie parts of the country. When it is sown in heavy land and where there is a large amount of rainfall extending from spring on into the fall, it is a most difficult plant to kill. This grass starts early in the spring and has a luxuriant leaf growth. On this account it is rather difficult to cure it for hay, so it should be left until it is pretty well matured before it is cut. In starting a field of brome, one should

procure good clean seed and sow this at the rate of about twenty pounds to the acre in a good firm seed-bed. This seed-bed may be on a summer fallow, provided there is no danger of the soil drifting. It is safer, however, to sow brome in stubble land that has been ploughed, firmly packed and harrowed. The seed should be sown about the last week in May or the first week in June. It is usually sown broadcast and then harrowed in.

How to Eradicate. Brome grass can be eradicated by ploughing just deep enough to turn the roots up to the wind and sun at a time when there is likely to be no rains and when the sun and wind are sufficiently hot to dry the roots out. This drying process can be hastened by the use of the cultivator that will tear up the sod and bring the roots to the surface of the ground. It should not be sown anywhere around the garden or lawns or about trees, on account of the difficulty of eradicating it from such places, and because of the fact that flowers, shrubs and trees will not do well where Brome grass thrives.

Western Rye Grass. Western rye grass is a native grass discovered and improved through selection and cultivation by Mr. McIvor of Virden, Manitoba. This is a perennial, but it has fibrous roots instead of the perennial root-stalk, as described under Brome grass. For this reason, when the farmer

wishes to plough up his field for the purpose of sowing grain, it is easily eradicated. It has few leaves and rather wiry stems, but if cut a little on the green side is a very nutritious and quite heavy yielding grass. If it is left standing a little too long it gets very tough and wiry. It should be seeded like Brome grass.

Timothy. Timothy is another grass which has not been grown extensively in the prairie provinces. It is, however, one of our choicest grasses for the purpose of making hay for horses, as it has a fairly good leaf growth and makes a clean, palatable hay. Like the western rye grass, it has fibrous roots and is easily gotten rid of. It should be sown at the rate of about ten pounds to the acre in a seed-bed as described for the other grasses.

EXERCISES

1. Study the native wild grasses of your district.
2. At what time do your native pastures become green? At what time do they ripen?
3. Sow a few seeds of Western rye, brome and timothy in little plots in the school yard, and study their roots, stems, leaves and seeds.
4. How many acres of native pasture does it take to keep a cow? a horse? a sheep?
5. Are there any evidences of a need of grasses in your neighborhood? What are they?
6. When the grass is covered with snow in the winter, cover a small plot about one-twentieth of an acre with strawy manure, and compare this plot with that surrounding it, in May and June.

IX. WEEDS

What They Are. A weed is a plant that is growing where it ought not to grow. If a wheat plant is growing in a potato field, we should be quite justified in calling it a weed, but we usually attach the term weed to such plants as thistles, lamb's-quarters, wild buckwheat, sow thistle, French weed, wild oats, couch grass, and many others whose names and characteristics you will learn. Weeds are considered a great nuisance the world over. The farmer dislikes them because they occupy ground that should be occupied by more valuable plants; because they rob the crops of moisture and plant food; because their seeds, such as wild oats, wild buckwheat, thistle pods and others, are threshed with the good grain, and on account of their presence the quality of the marketable crop is of a low grade and the farmer must take a low price for it; because it costs time and money to harvest and thresh the weeds; because of the extra time that must be spent cultivating the soil for the purpose of killing weeds and giving them a setback so that crops may get a start of them; because they harbor injurious insects; and because of the decrease in the value of his farm due to the presence of such weeds as have been mentioned. While we all agree that weeds are very bad things to have on our farms, I am

sure that we shall all agree that even weeds have a good effect upon the careless farmer, for they force him to give his land better cultivation, resulting in larger returns. Then they force him to build fences and keep sheep, cattle and hogs. Sheep eat almost every kind of weed, and the manure made by the live stock enriches the soil and so makes it possible to go on raising good crops year after year.

Kinds of Weeds. Weeds may be divided into three classes: annuals, biennials and perennials. Annuals are those that grow from seeds every year, such as wild oats and French weed. Biennials are such as grow from the seed the first year and develop a thick fleshy root, and the second year send up from this root a stalk that bears flowers and seeds, good examples of which are burdock and dandelion among weeds, and turnips, carrots, parsnips and beets among cultivated plants. French weed is sometimes called a winter annual, because it starts in late summer from the seed, lives through the winter and matures seeds early the next summer. Perennials start from seeds and continue to come up from the roots year after year. The Canada thistle, perennial sow thistle, couch grass, sweet grass, and bindweed are examples of very noxious weeds that belong to this class.

How Weeds Spread. All weeds bear seeds at some period in their lives, and when these seeds find lodgment in the soil with proper conditions for

growth, they produce a plant which again bears seeds. Weeds such as French weed and wild oats, when allowed to ripen their seeds in the field, drop them all around the parent plant. From this place they are distributed over the field by the implements of tillage, such as the harrow. The stook wagons and separator carry weed seeds from dirty to clean fields. The wind carries soil and seeds long distances. Water running down from weedy fields carries with it many weed seeds. Sometimes we buy seed grain or feed that carries with it many weed seeds of various kinds. You will no doubt be able to think of other ways in which weed seeds of the kind mentioned are carried from dirty fields to new clean land; for example, those provided with little hooks for clinging to one's clothes and the hairs of animals.

Other weed seeds have light, downy wings on them, and on account of these they are able to float away on the breezes long distances from their native place, and after a while settle down on some well-tilled field, where in a few years the farmer is surprised to find a bed of some very noxious weed. Such weeds are Canada thistle, sow thistle and dandelion. Some weeds scatter themselves by means of running root-stalks which have buds at short intervals. Canada thistle, perennial sow thistle, couch grass and bindweed have this characteristic.

How to Eradicate Weeds. It is a very difficult matter to eradicate many of our bad weeds. Our farmers should take greater care in preventing them from getting a foothold on their farms. When only grain crops are raised, such as wheat, oats, barley and flax, it is practically impossible to get rid of wild oats, French weed, and others like them. They ripen earlier than the other crops and drop their seeds, and in time the ground is poisoned with them. We do know this, however, that if a seed germinates and we pull the little plant up and leave it on the surface to be dried out by the sun and wind, we have destroyed at least one. This would be much easier to do than to try to pick the seed from the soil, would it not? Now, this is the secret of destroying great numbers of weeds that grow from seeds. Cover up the weed seeds in the fall lightly with a disk or a gang plough. In the spring, as soon as the seeds germinate, tear them out with the harrow or disk. Repeat this harrowing process as often as possible, and every time large numbers of annuals will be destroyed. You see how necessary it is to study the nature and life history of a weed in order to know how to kill it. Our methods of summer fallowing should be of great assistance in eradicating weeds. Such weeds as couch grass and sow thistle should be ploughed just deep enough to turn their roots up

to the sun and wind at a time when it is likely to be hot and dry, so that the life may be dried out of the roots. For further information on weeds the teacher should see "Farm Weeds," a copy of which should be in every school, and also such bulletins as are issued by the Provincial departments of agriculture.

EXERCISES

Collections of the common weeds of the district should be got together, pressed and mounted.

Collections should also be made of the different weed seeds.

1. Compare the tame oat and wild oat, and note differences in form, color, hull, beard and other characters.
2. Take four ounces of grain as it comes from the separator and find the percentage of weed seeds in it.
3. If a 320-acre field averages 25 bushels per acre, and the dockage is five per cent., what is the loss when No. 1 Northern is selling at 89 cents?
4. Why are weeds sometimes called the "poor farmer's friends?"
5. Name two each of annual, biennial and perennial weeds in your district.
6. Name weeds in your neighborhood that are distributed (a) by the wind, (b) by clinging to clothes and animals, (c) by wagons, seed and feed.

X. CROP ROTATION

During the first few years on the prairies, farmers give little thought to the raising of crops other than wheat, oats, flax and potatoes. This is

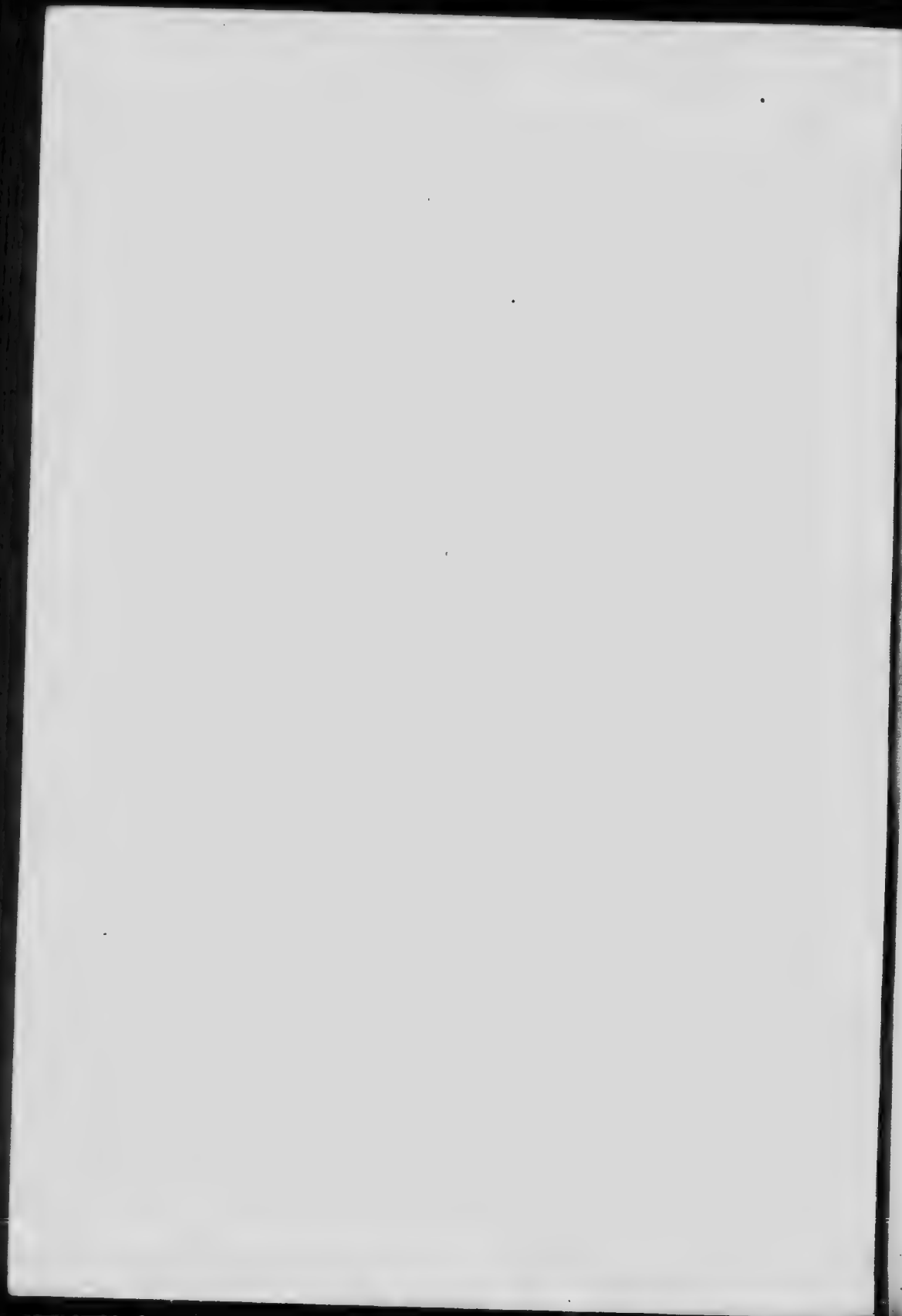
quite natural in a new country whose soil is as rich as ours, and whose people have come for the purpose of making a living and in some cases of making money out of wheat raising. It has been the case, however, in all countries, not excepting our own, that after such practice has prevailed for a time certain difficulties in crop production present themselves, and these have to be solved before profits can be secured from farm operations. Some of the difficulties are as follows: weeds get in and take possession of some of the best farms in the country; the soil on the heaviest, richest land drifts with the wind and leaves the seed uncovered and oftentimes destroys a whole crop; the soil after continuous cropping of wheat or flax seems to get sick and refuses to produce paying crops; soil fertility is sold as wheat, corn, flax, oats and barley from the farm and nothing returned to it. These are difficulties that are now presenting themselves to the farmers of the older settled districts, and they must be solved before permanently successful agriculture can be established. It is not that our soil fertility has been exhausted, for we have a large area of soil equal in richness to that of any other part of the world, but in many cases the physical condition has been so impaired by the exhausting of the humus that it drifts and will not hold moisture, and so is practically non-productive.



A WELL SHELTERED PRAIRIE PROVINCE FARMER'S HOUSE.



SIDE VIEW OF A PRAIRIE PROVINCE HOME AND FARM BUILDINGS—
SHOWING GRAIN FIELD IN FOREGROUND.



What is a Crop Rotation? By a crop rotation is meant that at certain regular intervals crops are grown in a field with a definite purpose in view, and that purpose is to put the soil in the best possible condition for the crop that is to follow. When a rotation of crops is practised, it means that the farmer is a student of soils, crops and animals. He plans his crops with a view not only of maintaining the fertility of his soil, but of making it better than when he began working it. Deep-rooted plants follow shallow-rooted ones; grasses and clovers have a place at regular intervals among the other crops; roots and other cultivated crops occur in their turn. In this way weeds are killed or kept in check; the soil is refilled with grass roots which act as soil binders and, when decayed, replenish the soil with humus; deep-rooted plants bring up elements of fertility from the lower depths; and harmful soil-bacteria are killed. But what is done with the various crops—grasses, clovers, roots, corn, peas—that are produced? They are fed to some of the different classes of live stock and converted into good horses for work, or into beef, pork, mutton, wool, eggs or milk for food. Manure is made and applied to the land, which in turn produces more abundantly. Thus we see that in order to ensure a stable, permanent agriculture, with comfortable farm homes and a prosperous, happy people, crop

rotation and animal husbandry are necessary and lend themselves as no other factors do in accomplishing these results.

EXERCISES

1. A farmer has 320 acres of land. He summer fallows 100 acres in 1909, grows wheat on it in 1910 and in 1911 burns the stubble and sows wheat again. Is this a rotation of crops?
2. What will be the effect upon the soil if such a procedure is followed?
3. Draw a diagram of a 320-acre farm, letting one inch represent 40 rods. Show on it a rotation that would be suitable for a live stock farm, and write down the numbers of the different classes of live stock that might be kept on the farm.
4. How many bushels of wheat, at 25 bushels per acre, should be raised on such a farm under a good rotation?

REFERENCES

The teacher should bear in mind that only a few of the principal crops are dealt with in this book. For further information in regard to those dealt with, and the many others that may be taken up, the teacher should consult the following:—

- Dominion Experimental Farm Reports, published at Ottawa.
- Bulletins published by Provincial Departments of Agriculture.
- Bulletins published by United States Department of Agriculture.
- Bulletins published by Experiment Stations at St. Anthony Park, Minnesota; Fargo, N.D.; Bozeman, Montana.
- Report of Irrigation Conventions, published by Department of the Interior, Ottawa.
- Physics of Agriculture—KING.
- Soils—HILYARD.
- Cyclopædia of Agriculture—BAILEY.
- Soil Fertility and Permanent Agriculture—HOPKINS.

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